metal treatment

Vol. 26 : No. 163 APRIL, 1959 Price 2/6

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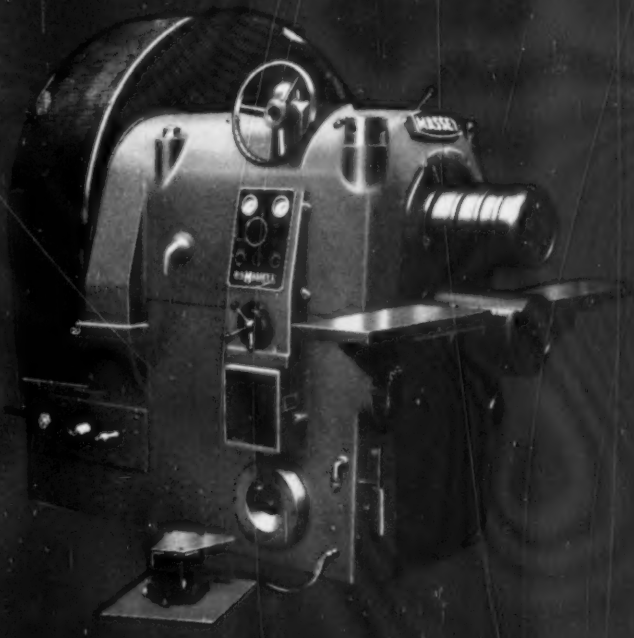

FEATURES

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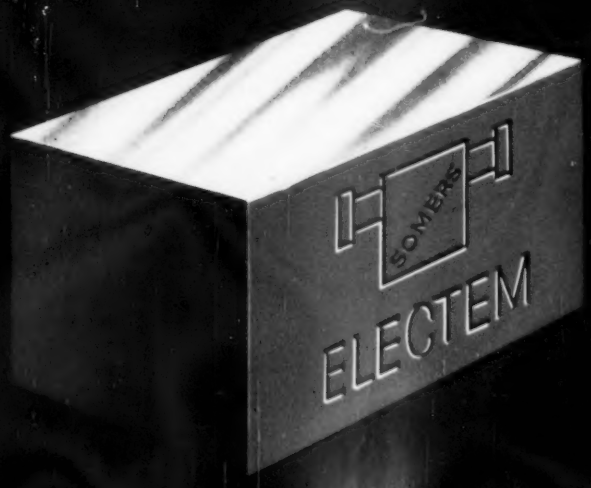

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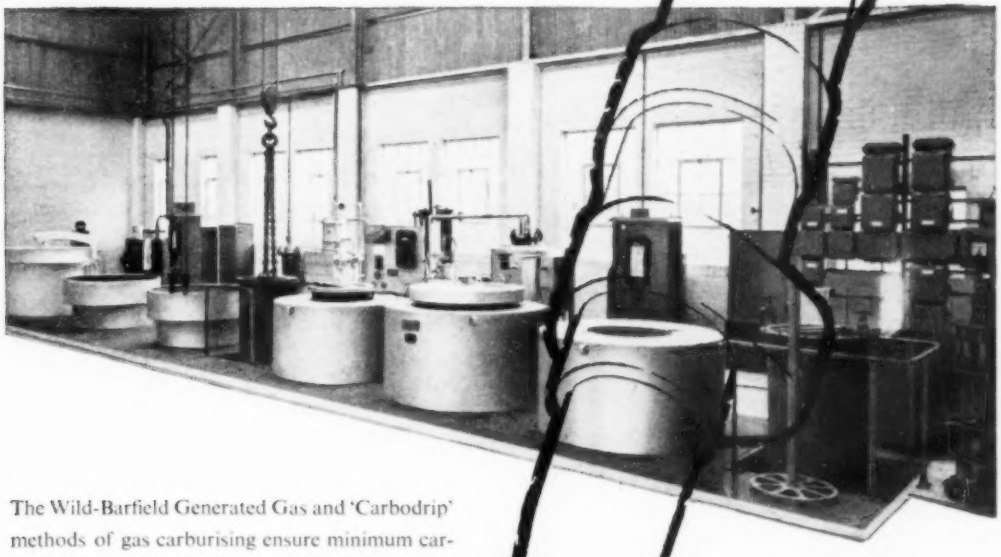

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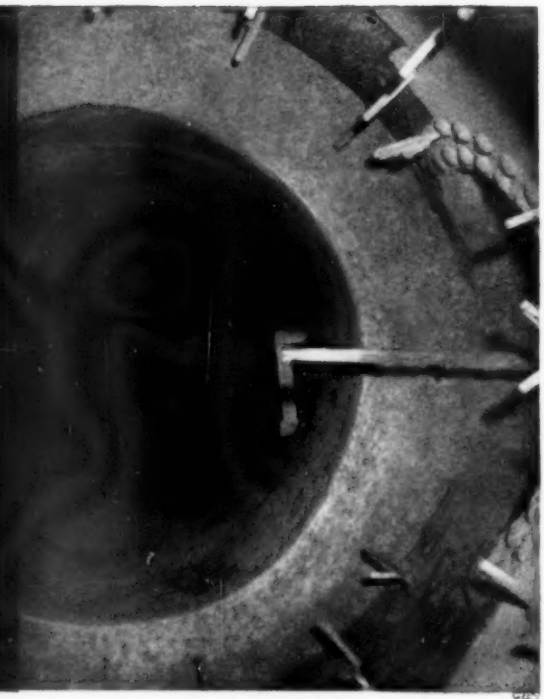

Bustle main of Queen Victoria Blast Furnace showing 'gunned' lining in Tri-Mor Dense 'Guncrete'.
(Inside diameter of shell 5 feet. Thickness of 'Guncrete' lining 9 inches).
Photograph by courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Companies Ltd.).

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TRI-MOR *Standard Castable*
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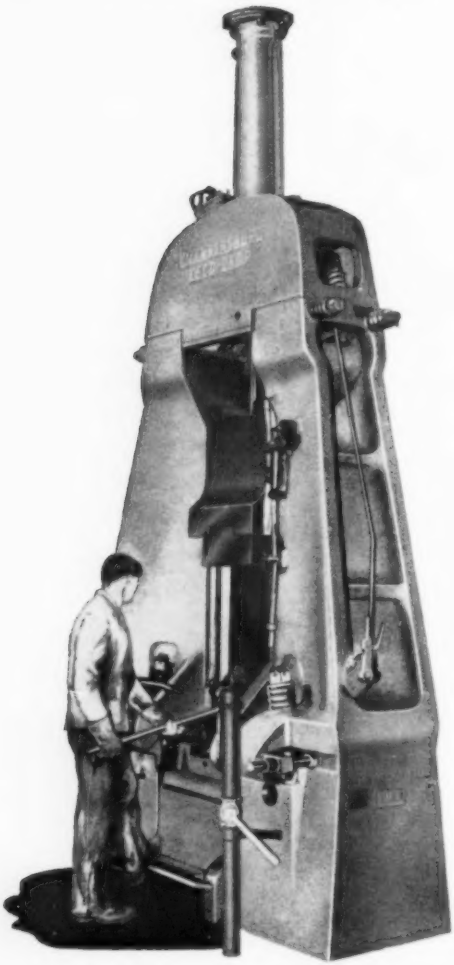

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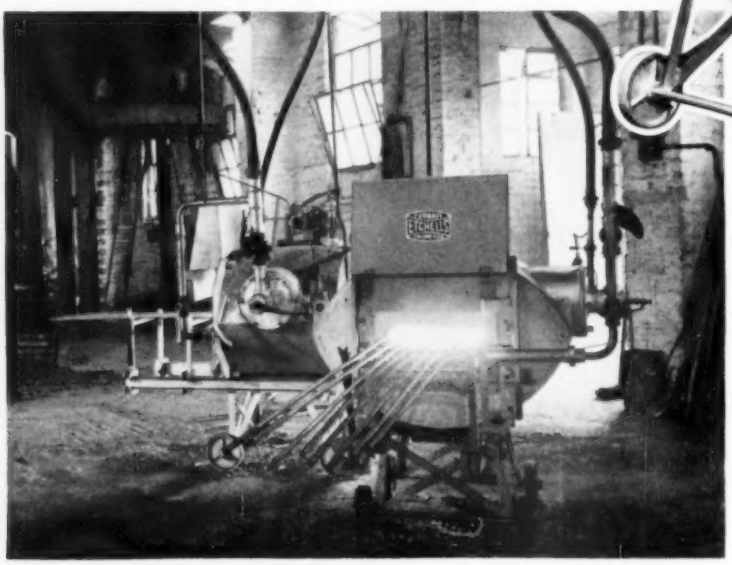

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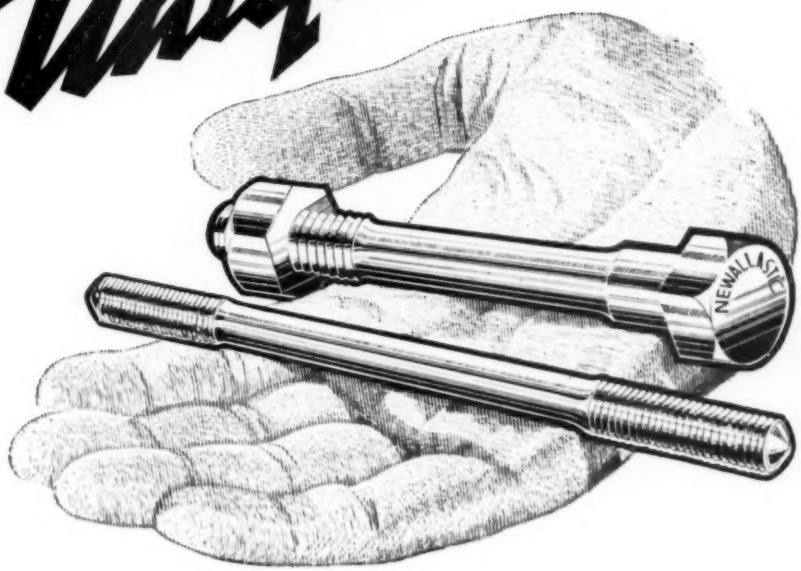

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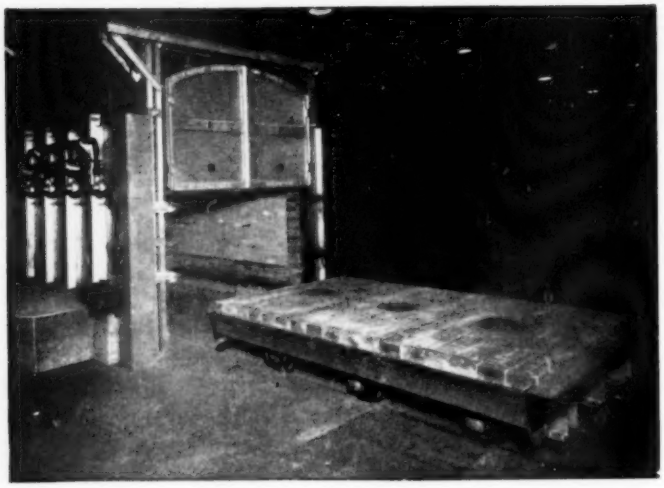

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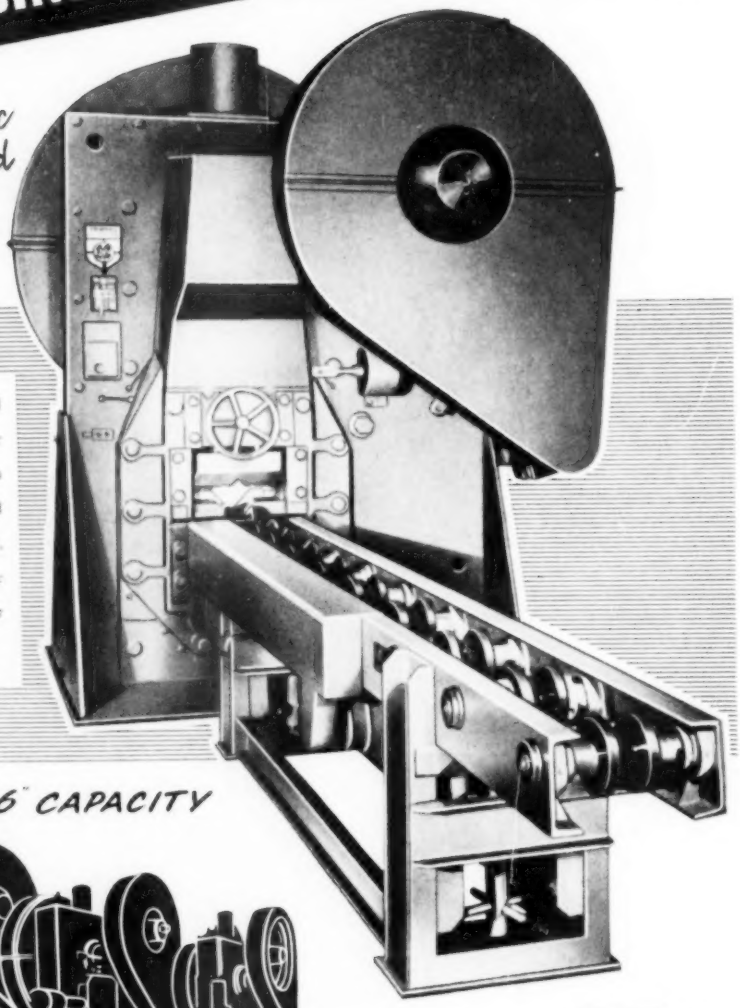

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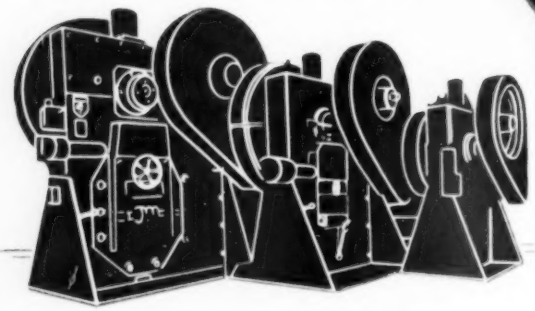

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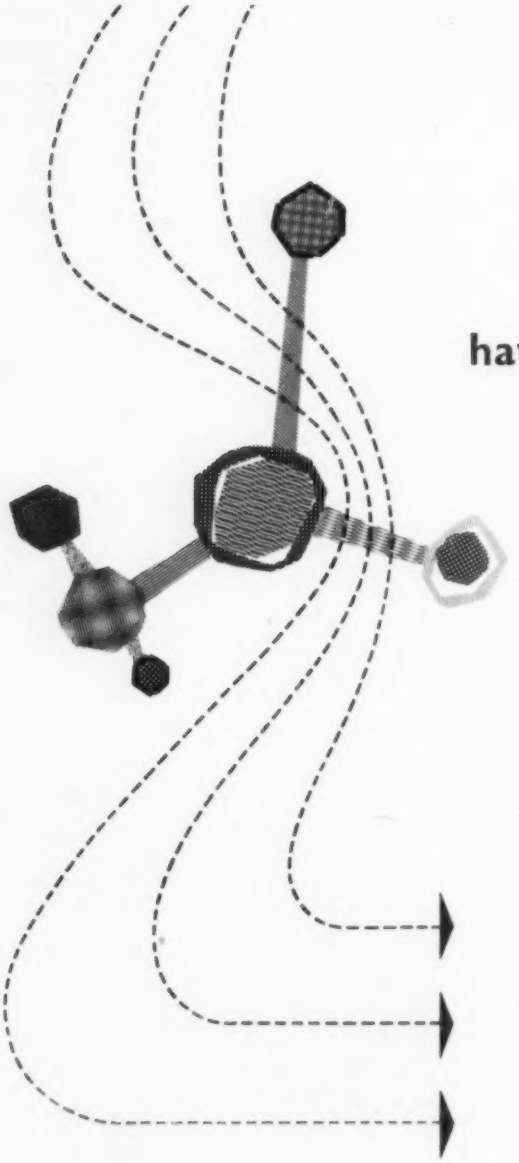

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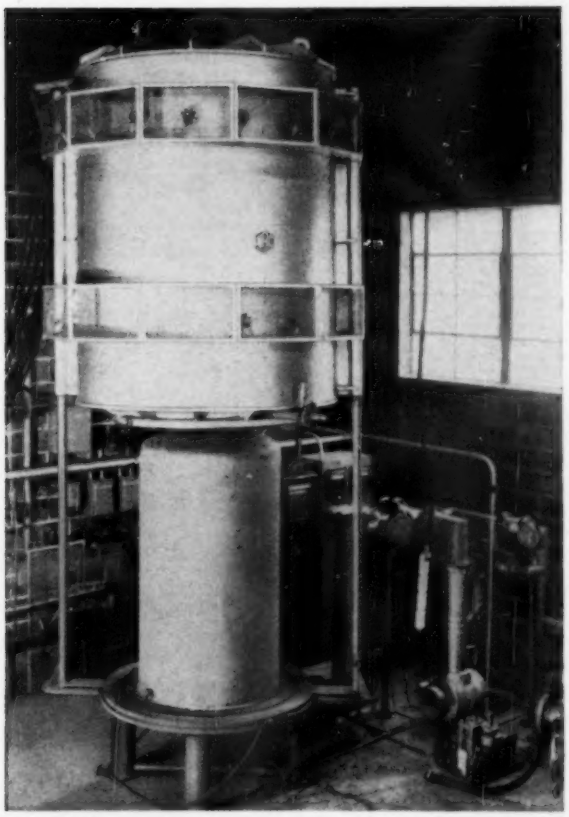

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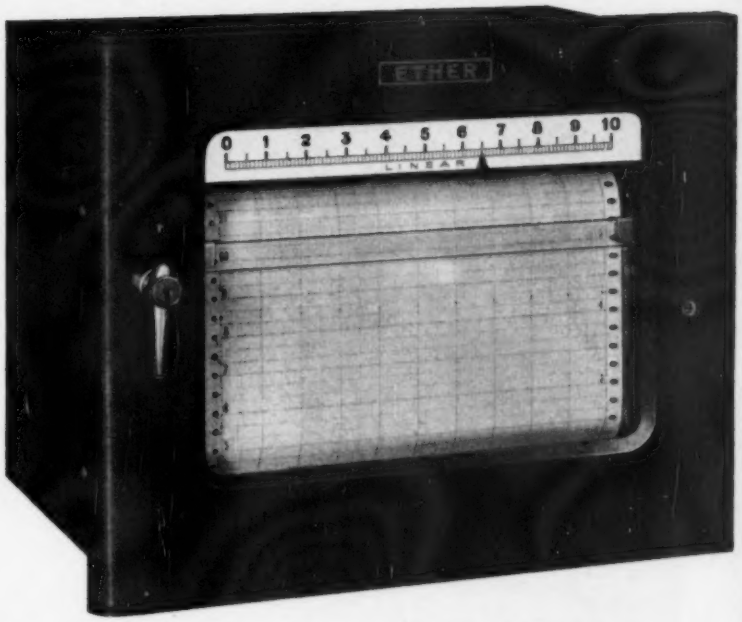

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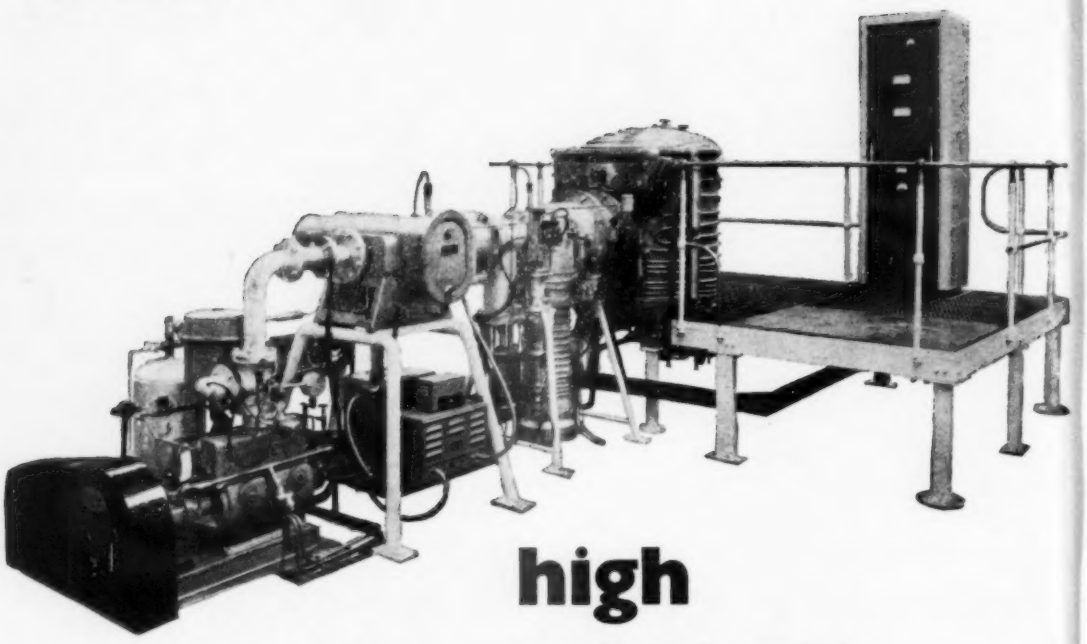

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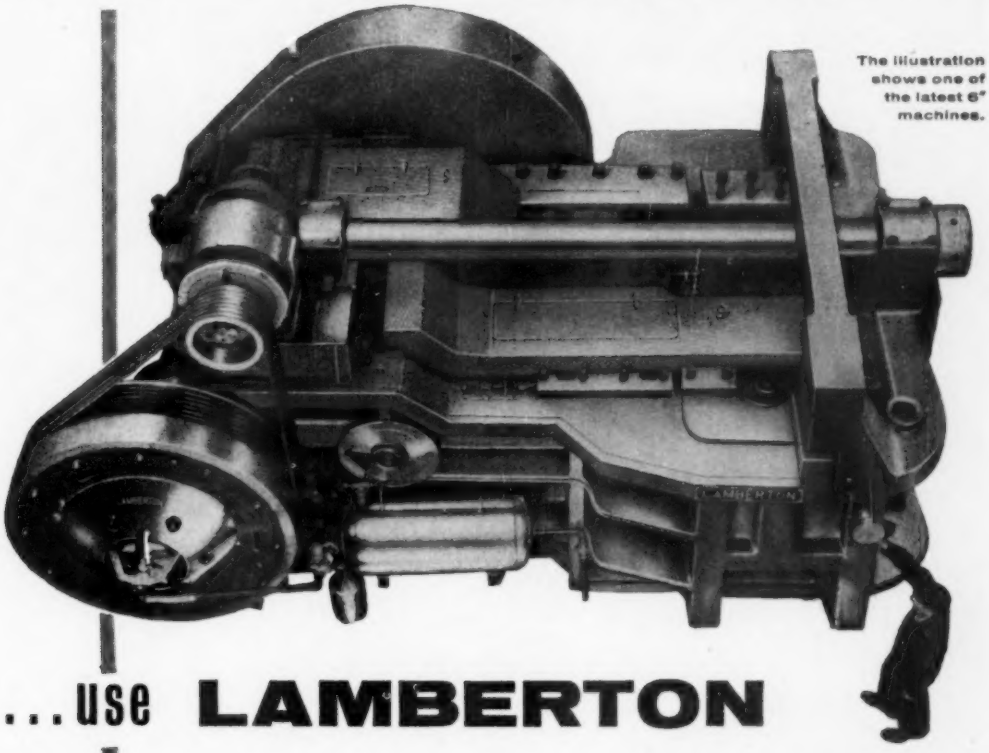

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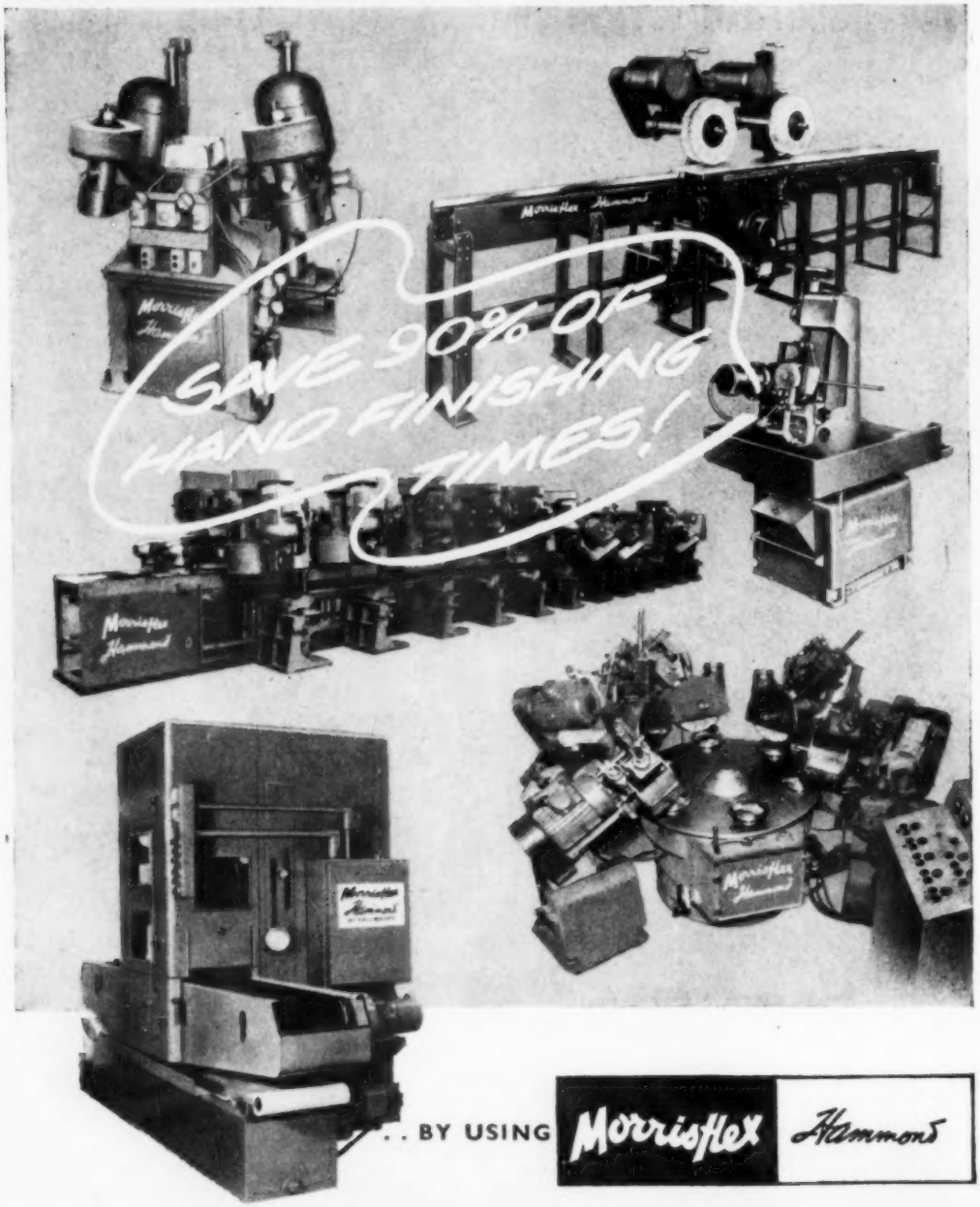

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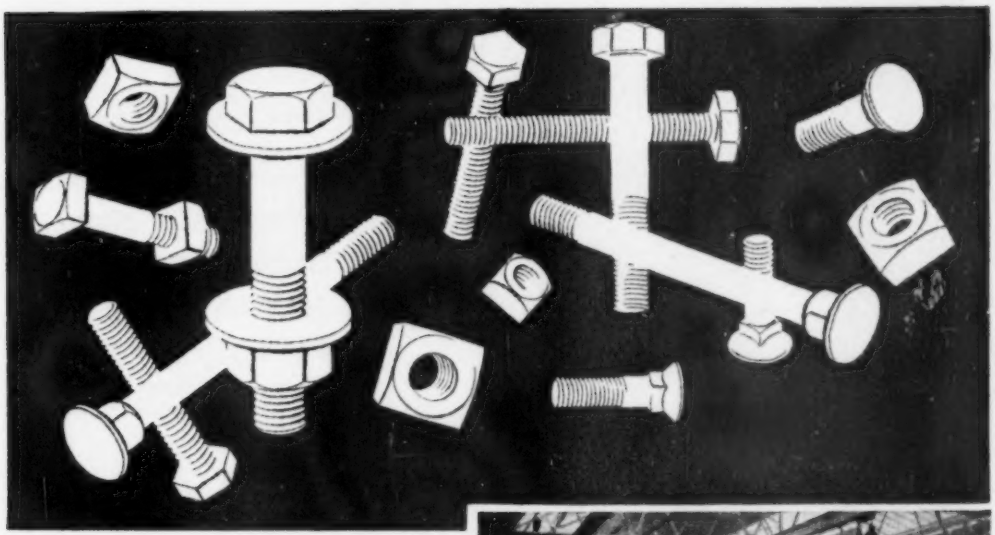

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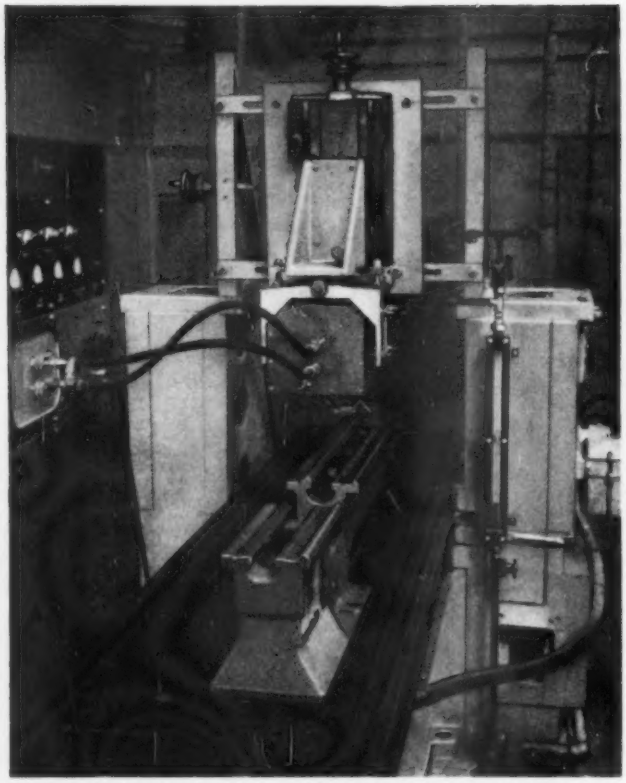

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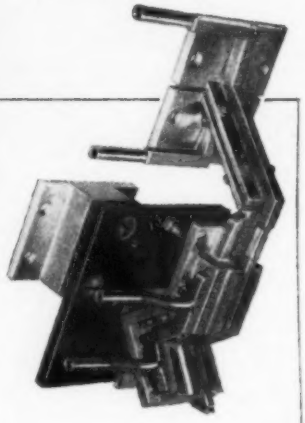

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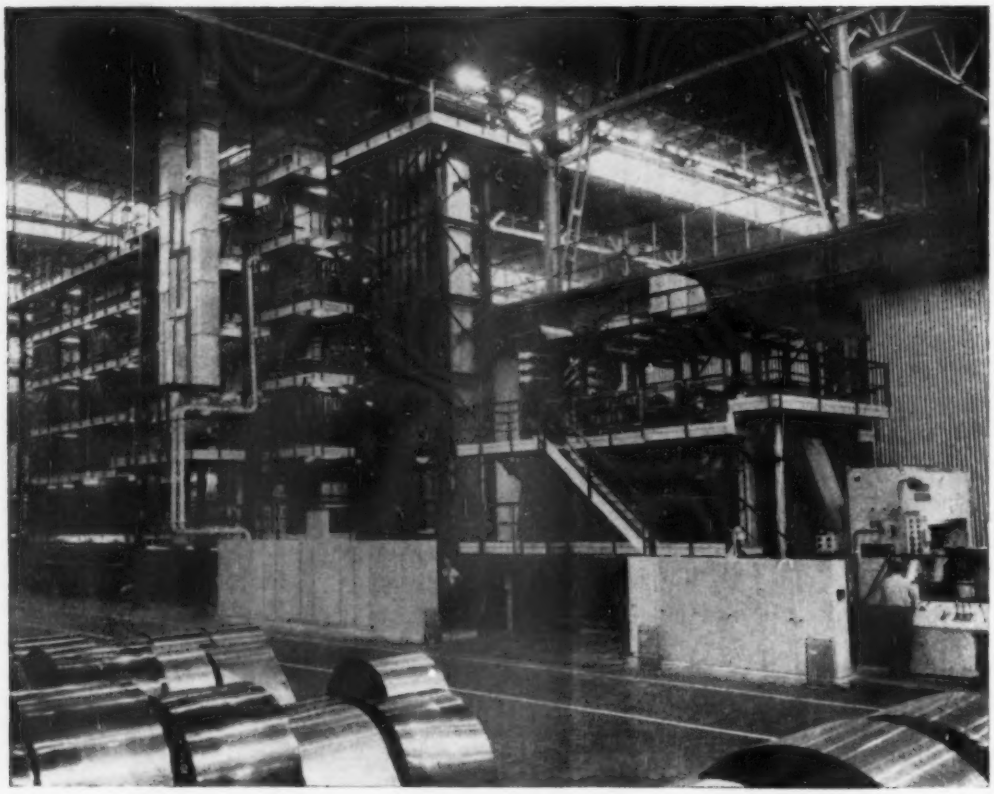

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and Drop Forging

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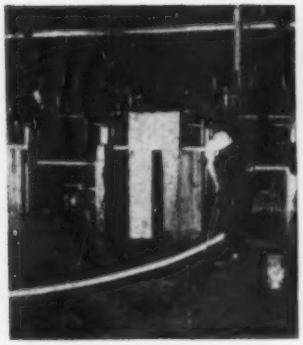
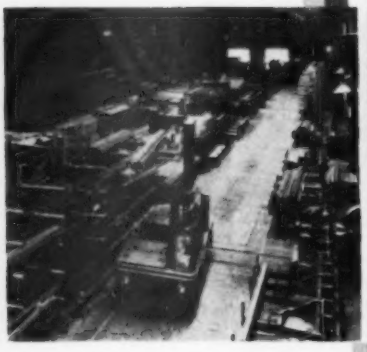
Precision ground and Centreless turned Bars





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Flat-footed

A GREAT pity, because it started off so well! We were introduced to the new B.I.S.F. film 'Men of Consett' by some magnificent scenes of the harsh, wild moorland country on the Durham-Northumberland borders. A land of wide spaces, blue horizons, purple heather and rolling clouds, this was shown to us in excellent colour with an enchanting background of bird song—the long bubbling whistle of the curlew's springtime call. Then to the sea, for glimpses of the rugged coastline and the sound of seagulls, a brief flash of white flickering across the screen, just long enough to be recognized—a fulmar. And so to the real subject of the film, Consett iron works and the men who work there, a subject tackled without benefit of professional actors and therefore not altogether easy—but was it necessary to be quite so flat-footed in putting over the propaganda message?

We start by entering the works main offices with the producer-narrator and meeting the managing director and other works officials. These scenes are well and convincingly enacted by real-life people, but are we really expected to believe that visitors to Consett are normally told that once during the war a load of sugar was delivered by mistake in place of a load of sand? (When we were privileged to visit Consett, this interesting piece of information was withheld from us.) By itself this remark is of no importance, but unfortunately much worse is to come. The narrator and his companion want a drink after two o'clock on Sunday, and find the pub closed. This elicits the truly astonishing remark—'They'll be nationalizing beer next!'—and the even odder reply 'And putting sand in it probably!'

Now this is just a bit too much. Intelligent men do not normally talk in *non sequiturs*, and we cannot be expected to believe that they do at Consett. The fact that public houses are compelled by law to close at 2 p.m. on Sundays has nothing whatever to do with nationalization, socialism, the Labour Party or any other political spoke in the steel industry's wheel. It dates from an Act of Parliament passed some forty to fifty years ago which has never been repealed, and which does not appear likely to be repealed in our lifetime; more's the pity! To suggest that it presages the nationalization of the brewing industry is both childish and dishonest.

Finally, after seeing more impressive shots of the blast furnaces and steel-making plant at Consett in operation (the night-shift scenes and the suggestion of the colossal heat generated in a melting shop are both excellent), we see the narrator catching the train away from Consett station. A friendly type, he congratulates the engine driver on having charge of a fine piece of steelwork in the form of a locomotive, and commiserates with him on the fact that it is painted black. But the engine driver knows that this is only half the dismal story, he has heard (and his voice makes it clear that it means bankruptcy or worse) that 'they are going to paint them all green again!' (Or was it blue? We can't remember!)

Now the steel industry has every right to spend as much money as it wishes to counter the threat of nationalization, but most emphatically this is not the right way to go about it; nor, we regret to say, was the recent public opinion poll by Mr. Colin Hurry. Educated and intelligent people, who are in large measure the 'floating voters' who decide the outcome of elections, know that it is elementary logic that you cannot hold opinions on matters of fact. Either nationalized industries *do* have more officials than non-nationalized ones or they *do not*; reference to the relevant statistics can decide

which is the true answer. To ask an intelligent man to give an *opinion* on the matter (as one of the questions did in Mr. Hurry's poll) is tantamount to calling him a fool! In 1945 a well-known Press Lord was ladling out much the same kind of incredibly inept propaganda by the bucketful, and it was generally agreed later that he had lost his party millions of votes if not the entire election. If the British Iron and Steel Federation can't do its job with a little more respect for the intelligence of the British public it'll find itself in the same position in 1959!
Still—the curlews were nice.

Expansion

A YEAR AGO we wrote the monthly 'leader' for METAL TREATMENT from a hospital bed, which perhaps explains why what we wrote at that time has remained so clearly in memory. Concluding a brief discussion of some of the manifestations of the trade recession, we suggested that whatever the final outcome, one thing was certain—that to the 'uncommitted' nations of the world the Western way of life was on trial. If we were unfortunate enough to slip back into the kind of slump which was experienced in the 1930s, then we suggested Russia and the Communist bloc would gain an outstanding victory without the need for dropping a single bomb or calling up a single soldier.

We were therefore very interested to come across the article entitled 'Why Restrict Output?,' by Mr. Anthony Vickers, managing director of Fluidrive Ltd., which appeared in *The Engineer* of February 20, 1959. For Mr. Vickers concludes with very much the same sentiments: '. . . And, looking to the future in Russia, where the monetary system is designed to permit full and expanding production, how shall we measure up in ten years' time? Shall we and the other Western nations continue to restrict output or shall we dare to allow production to expand by matching it with increasing demand?' Mr. Vickers' article is an interesting and thoughtful analysis of some of the effects of the trade recession and the part played by the monetary system. Why, he asks, should it seem essential that the output of this or any other country should be restricted, and his general conclusion is that it is only outdated habits and rigidities of the monetary system that make it appear essential. In this, of course, Mr. Vickers is not being either entirely new or original, for although he does not mention it, his analysis is broadly similar to that of the late J. Maynard Keynes in his famous 'General Theory of Money.'

Keynsian economics, as they are sometimes called, have now entered into the life of nations far more than may sometimes be realized. Perhaps the first and most interesting exercise on these lines was the 'pump-priming' experiments undertaken by President Franklin D. Roosevelt in his efforts to lever the American economy out of the appalling depths of stagnation into which it had fallen in 1933—efforts which, be it noted, were far from being an unqualified success. Similarly but in the reverse sense, the restrictions clamped on to the British economy in 1945 by the Labour Government, faced with a huge excess of purchasing power and a greatly shrunken productive capacity, also owed their conception to Keynes. And seeing that inflation went on practically unchecked (except in small spasms) from 1945 to 1957, these operations cannot be regarded as wholly successful either.

Once more we are back at the point where the 'pump must be primed,' *i.e.* purchasing power must be injected into the economy, and in the Budget of 1959 this has been to some extent accomplished. What we now must wait to see is whether we can at last expand the economy without inflating it.

The forging industry

Past, present and future

G. H. JACKSON, F.I.M.

This article, which will be concluded in next month's issue, is based on the first lecture in the series 'The forging of steel,' currently running at the Wolverhampton and Staffordshire College of Technology. The author, who is Technical Officer of the NADFS, first traces the development of forging hammers and open and closed-die forging techniques

HISTORY INDICATES that the forging of metal reaches back almost as far as civilization itself. It is recorded in the Bible that Tubal-Cain, seven generations removed from Adam, was an 'artificer in brass and iron.' In Greek mythology, Vulcan was accredited as the 'god of fire and the patron of workers in metals.' It will be remembered that it was Vulcan who was reputed to have forged the thunderbolts for Jupiter and the love arrows for Cupid. The Germans held Wodin to be their 'god of the forge.' In a Scandinavian legend, Thor is supposed to have possessed a hammer on which he formed a chain of spider-web thickness, yet strong enough to prevent anyone becoming entrapped from breaking loose or escaping.

Early history

When man first built his wood fires in contact with iron stone and produced metal, he realized its value if only it could be shaped. One can imagine him idly striking it while hot with a handy stone or some suitable implement and finding that its shape could be altered. As the art grew, craftsmen emerged from their earlier role of serfs to reach a status of respect which, partly through the early Guilds, continued to prosper even when other arts suffered a serious decline. Nations became dependent upon these artisans for the production of weapons and armour and, to a lesser extent, agricultural implements. The skill of the forger determined the efficacy of weapons which, in turn, won or lost a battle. Hence the secrets of the arts remained with families, being passed from father to son for many generations.

Progress was slow and developments few and far between. Today the steel or other metal is prepared for the forger, but in those days he was his own iron-maker, steel refiner, designer, forger, heat treater and salesman, a combination which must have demanded a patience unknown today. Steel was first made by packing small pieces of wrought iron into a carbonaceous material and heating, after which the pieces were laboriously hammer welded until a piece of sufficient size was obtained to suit the article being made.

Naujoks[1] quotes the Indians as being early forgers and instances the swords of Damascus, each of which, it is reported, 'was laboriously hammered at a hillside forge until it resembled the colour of the moon, when it was quenched by driving it into the thigh and leg of a slave.' It is noted that 'slaves were plentiful but a good sword was valuable'! Toledo and Balboa were also noted for the excellence of their swordsmiths.

By A.D. 1200 the Japanese were also known to be superb swordsmiths. In a recent article[2] it is mentioned that the sword or the 'tachi' was a favourite Japanese weapon which had been developed to a fantastic degree. The long single-edge blade was forged in one piece and was built up of numerous layers of thin steel by hammer welding. It is not quite clear whether a thermal treatment was carried out or whether a temper was developed by cold beating or hammering, but the quality was outstanding. It is said that blades could cut through four bodies placed upon each other and could cleave a pile of copper coins without nicking the blade. Experts consider that the 10th-century Japanese swords were superior to the best products of Damascus and Toledo.

It must also be realized that these very early workers must have experienced very great difficulty in achieving high enough temperatures to work their iron and steels, and it is not quite clear how they created a sufficient draught of air to draw their fires. It is probable that early use was made

of up-draughts created by natural chimneys in caves, using charcoal as the fuel.

Little is recorded of progress up to about A.D. 1200, but about this time the advent of gunpowder radically changed the type of weapon required and this stimulated development of the production of iron and steel in many countries and, simultaneously, the means of forging such larger masses. As the mass to be forged grew in size, the problem of heating the ingot or billet grew and it was about this time that the ingenious ' trompe ' was devised. This worked by entrapping the air in falling water which was imprisoned under pressure in a box, and was then led away in pipes to produce a blast for heating. As needs made still further demand upon man's inventiveness, water was used to drive a wheel which operated crude bellows, thus increasing the supply and pressure and volume of air available for heating.

Forging in Germany is known to date back to 400 B.C. Lange[3] has written that many of Germany's early forges originated on the southern fringe of the Ruhr, particularly in the Sauerland where many old water-driven trip hammers can still be found working to this day.

A trip hammer was a simple machine: a massive shaft or wheel, usually made of oak, was driven by a water wheel. On the periphery of the shaft or wheel were placed rows of iron pegs suitably spaced. On revolving, a peg would engage the end of a pivoted arm on the extremity of which was a hammer head, lifting this head until the peg disengaged, when a blow would be struck. The weight of the head was from 100—300 lb., though in 1852 the same principle was used by Krupp in Germany in the building of a steam-driven 15,000-lb. hammer. Up to 200 blows per minute could be struck with a water-driven hammer, the number of blows being easily controlled by the rate of water flowing to the wheel.

Helve hammers of this type were also to be found in Britain. The principle of the helve hammer is used today with, of course, modern powering. It has a rapid blow rate and lends itself to many fullering, flattening and drawing out operations.

In the early part of the 13th century the advent of pig iron radically changed the fortunes of the small trip hammer forges. Bigger plants took over the main engineering works whilst the original forges continued to make those articles required in small quantities of diverse design. Agricultural implements, mining tools and wood-working requirements continued to be made by the old methods and are still being produced in this way today in a few remaining forges.

Though there are forges in this country which can claim two-and-a-half centuries of continuous history, there is one that is probably unique. The Kirkstall forge was founded at a monastery by a small band of Cistercian monks in the hamlet of Kirkstall, Yorkshire, in A.D. 1200. This forge has remained in almost continuous production ever since, a period of some 750 years. For 125 years of this period, five generations of the Spencer family shared its management, and the present management, the present Butler family, have been owners and active managers since 1779. The history of progress of this company throughout the ages is the subject of a recent book entitled ' The History of Kirkstall Forge '[4] and is a well worth-while study for students of the history of engineering.

A.D. 1200—1800

Between the dates 1200 to 1800, development in the forging industry was slow and ponderous. It is obvious from the histories that a constant race took place between, on the one hand, the need for larger forgings and, on the other, the availability of suitably sized hammering equipment to manipulate them.

In the 19th century the application of forging to metal working began to split into well-defined arts which have existed to this day as specialized industries such as bolt-making and chain-making, to mention but two examples.

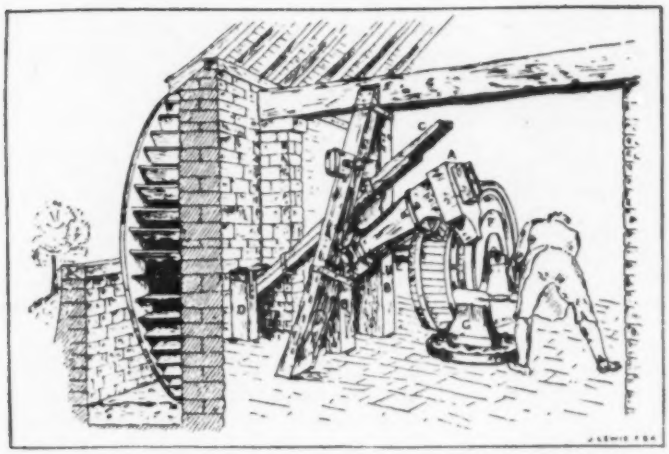
Bolt-making

Bolt-making developed simultaneously in this country and in the U.S.A. The early history of bolt-making is very obscure, though bolts were known to have been made thousands of years ago.

In 1830 Oliver invented the first bolt-making machinery at Darlaston. In 1839 Rugg introduced the industry into America and many improvements to the Oliver took place relatively rapidly over the next decade. America was particularly active in inventing equipment for the more rapid production of bolts, rivets and screws, a development greatly stimulated by the introduction of screw-cutting machines. In 1887, America perfected a three-blow heading machine and it is at this time one finds first mention of thread-rolling machines. This development of heading in the bolt industry led through logical stages to the machines of heavy upsetting capacity which today form a specialist part of the closed-die drop-forging industry.

Chain-making

The sister industry of chain-making is just as old in its origin. Slave chains dating back to 150 B.C. have been found at Bigbury Camp. The chain cable trade in this country, situated in the Black Country, was introduced by Noah Hingley in 1820, where it grew to become an important



1 LEFT *Water-driven tilt hammer*

From "Wealden Iron", by Ernest Straker

2 BELOW *Steam Oliver*, 1880

B. & S. Massey Ltd.

industry. Together with chain, ships' requirements of anchors and similar specialist fittings such as shackles were developed by the chainsmiths in the same district. This extension of the chain industry explains why so many ships' fittings are made removed from ports and shipbuilding centres.

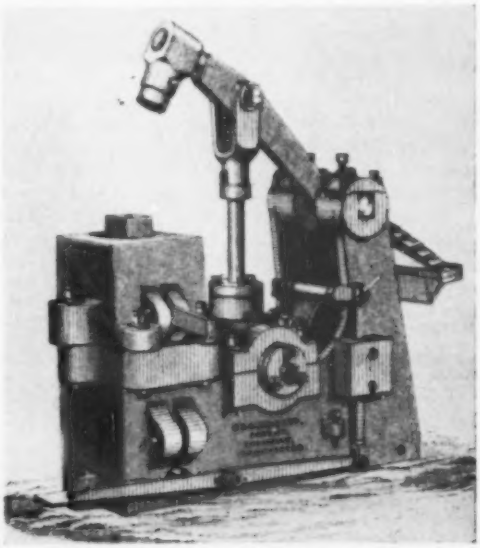
Early chain-making was carried out by hand hammer welding, but the early Oliver was soon adapted for chain requirements. The chainsmith of today still uses a modern Oliver for his work.

Steam

The development of the forging hammer became very active in the early 1800s. Up to this time, water was the main source, if not the only source, of power for the bigger helve-type hammers then built.

The advent of steam resulted in a big step forward in powering equipment for forging. Naujoks[5] quotes from a cyclopaedia published in 1831 by the Rev. Dronysius Larnder describing the application of steam for driving a helve hammer. The helve was lifted by a three-throw cam which, in turn, was steam driven. The hammer was reputed to be 6 tons in weight and capable of operating at 150 strokes per minute. This hammer was situated at the Milton Iron Works in Yorkshire and weighed in all some 40 tons, this weight including what we now call the anvil or sow. There is little doubt that this description covers the first application of steam to any forging plant.

In about 1838, James Nasmyth, a Scots engineer, received an order to forge an unusually large component for a paddle-driven steamer. No hammer big enough existed to execute the order



and so he set to to design what was to be the first steam-powered forging hammer.

Schofield,[6] in a recent article, discusses Nasmyth's progress in this project. Having designed the steam hammer, its original need was made redundant by the displacement of the paddle steamer by screw propulsion. Thus Nasmyth's ideas lay in abeyance.

His original design had, however, been seen by a Frenchman called Bourdon who, unbeknown to Nasmyth, proceeded to incorporate the invention into a hammer which went into production. Thus

the first steam hammer was built in France, due probably to the lethargy shown in Britain to an outstanding advance in an industry. In 1850, Benjamin Hingley proved himself a pioneer by installing the first steam hammer in the Midlands at Netherton, the erection of which was personally supervised by Nasmyth.

The application of steam in the forging field was rapid. In a catalogue dated 1885, the firm of B. & S. Massey, of Manchester, catalogued no less than 15 steam hammers for various applications. A further catalogue on bow-framed hammers quotes from *The Engineer*, February 8, 1884: 'Annexed we give an illustration of a powerful steam hammer recently constructed by B. & S. Massey, which presents some important improvements as compared with those usually constructed in this form.' This, it was claimed, would be made in all sizes from 10 cwt. to 20 tons and upwards.

In a similar catalogue of the same company, interesting reference is made to early definitions of ' what weight of blow does the hammer make ?' It quotes ' The force of a blow cannot be stated in terms of weight at all because the pressure of a weight is continuous, whereas the force of a blow is expended in a moment. It has, however, been ascertained by careful experiment that the maximum blow of a 5-cwt. double-acting steam hammer with moderate steam pressure produces a crushing effect upon a piece of hot iron as great as that produced by a load of about 30 tons.'

Today, double-acting steam hammers are much favoured in certain industries and many installations are made up completely of these children of the Nasmyth conception.

Drop hammers

During the steam developments, the drop hammer, much in the form as we know it today, came into existence and was developed according to several needs. The early type ' kick ' hammers involved much man power and little mechanical assistance. The tup or falling weight was lifted by a belt passing over a pulley, the frictional contact being a result of a man who literally kicked his weight on to the tup belt to produce the necessary friction to lift the hammer. The blow was then effected by the free falling weight. As the need for heavier hammers grew, this type of kick stamp became rapidly inefficient from the point of view of the sheer number of men required to lift the tup. As early as 1836, John Nuttall had devised a belt-lifted hammer using friction rollers.

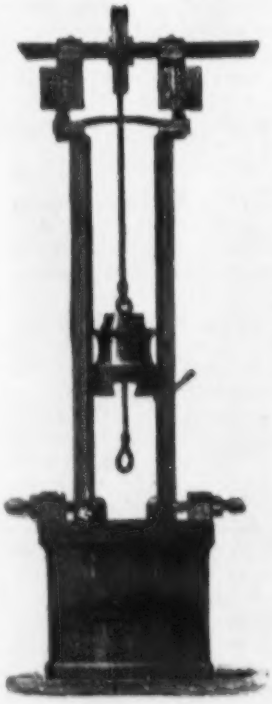
The first board hammer is accredited to America in the year 1862. In the catalogue of 1885 previously referred to, one finds an advanced British board hammer which, it is said, was obtainable in any size from 1 to 15 cwt.

The timber board was attached to the tup and passed through a pair of rollers on the head. One of the friction rollers is movable horizontally so that the board can be lifted and then released.

Dies

Up to about 1850 shaping under a hammer had been carried out on flat-faced anvils or, at the best, roughly gouged blocks, to give an approximate shape. Credit for sinking the first closed dies as we know them today is given to two Americans—Root and Billings, of the Colt Arms Co., of Connecticut. These dies were required for the continuous production of precision components for various pistols and rifles.

F. J. Somers,[7] in an article, suggests that the earliest impressions in England may have been associated with Huntsman crucible steel development in as early as 1730, as implements made in those days could not have been fashioned only on the anvil. He suggests that there may be grounds for supposing that dies as we know them originated during the Napoleonic era as a means of producing sufficient weapons for Napoleon's armies.



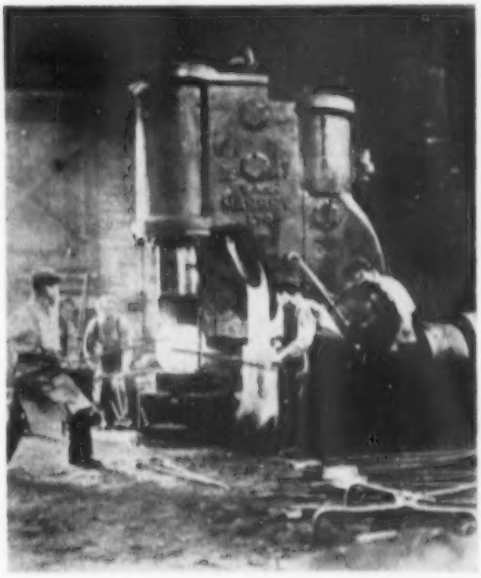
3 *Kick-stamp*, 1870

Somers feels that such impressions were utilized by lock and key makers in the Willenhall district between 1830 and 1840. It would seem fairly clear that, whether in America, France or England, the first true closed dies were the result of the demand of armies and weapons. The development of the closed-die technique proceeded in parallel in U.S.A. and in England.

The preceding discussion is a review of history. It is a story of slow development and the application of power as it became harnessed by man. Firstly, gravity has always been a main source of force. Water, steam, air and, finally, electricity have each in turn been applied as a means of lifting heavier and yet heavier weights.

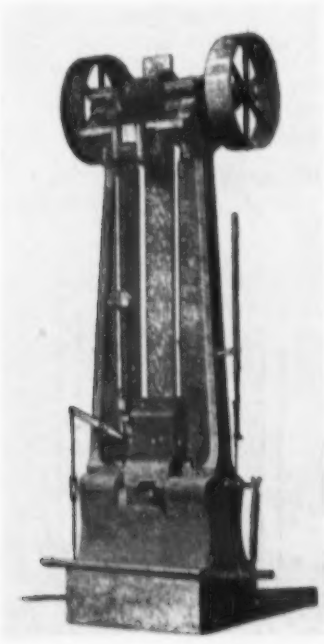
As one traces the history, it becomes apparent that there was constant fluctuation between the requirements of bigger hammers and larger masses of steel to feed them. Thus we read that in 1851 Krupp in Germany successfully produced an ingot weighing 2½ tons. The progress made by Bessemer in steel-making in England marked a big step forward in large ingot production. The steel industry rapidly overcame the deficiency of large ingots until today we see 250-ton ingots being produced for massive forgings such as boilers, stators, and other large turbine and engine parts.

The invention of the automobile and, later, the development of the aircraft industry, did more to stimulate rapid progress in the forging industry than any other requirement of engineering. Their requirements of quantity, quality and, above all, dimensional tolerances, have been responsible for the growth of the drop-forging industry as we know it today.



B. & S. Massey Ltd.

5 *20-cwt. pneumatic hammer*, 1938



4 *Beard drop hammer*, 1880

Divisions of the forging industry

Since the 19th century, the art of forging has become clearly divided into three main processes, namely that of the blacksmith, the forgemaster, and the drop forger and stamper. These three categories are differentiated mainly by the working tools used. The smith fashions the metal by hand with such simple aids as the anvil, whereas the forgemaster does the same on a more massive scale. It is free forging, the final shape depending entirely on the skill of the forger. Drop forging, although deriving its name by its use of the drop hammer, utilizes closed dies as the means of shaping. On the face of it the drop forger has little to do other than operate the hammer but, even with the aid of closed dies, considerable skill is still required to produce the forging.

Two main types of equipment are used by the forgemaster, the hammer and the hydraulic press. The hammers are usually pneumatic for smaller work and steam for heavier sections. The pneumatic hammers are very accessible and compact

and deliver forging blows at a rapid rate. Steam hammers of much heavier capacity are usually double-acting, that is, the steam is used to lift the tup and then to add to the force of gravity on the down stroke. There are several designs of such hammers, differences mainly being in frame design. Thus there are double-frame and single-frame hammers, the single-frame type sometimes being referred to as a 'C'-frame hammer. The single-frame hammers usually range in size from ½ ton to 3 to 4 tons capacity, whereas the more strongly built double-frame hammers range up to 10 tons.

Foundations

Such hammers require massive foundations, firstly to support the great dead weight, and secondly to absorb the energy of each blow. The anvil or sow block of these hammers is usually 20 to 30 times the weight of the falling tup; thus a 10-ton hammer may well incorporate a 300-ton cast-steel sow block.

Foundation requirements are relatively common to all types of hammer. These requirements necessitate a careful choice in siting, both from the point of view of geology, and particularly from the aspect of vibration transmissions. Older-type foundations consisted of a huge block of concrete capped with baulks of timber to support the hammer. Modern tendencies still utilize reinforced concrete, but the need for vibration isolation from surrounding properties has resulted in the installation of spring foundations. Both steel springs and rubber or rubber-like materials are used in the mountings, but it must be understood that correct damping can only result from a careful study of the many factors involved. Much work has been done on this subject by Crockett and other workers. Like the iceberg, there is more of the hammer below ground than above, at least when measured in weight.

To return to the tools of the forgemaster. The hydraulic presses used vary from 600 tons capacity up to 10,000 tons. Such large presses can manipulate ingots of 250 tons in weight which are slowly worked by chain manipulators, which rotate the mass under the guidance of the hammersmith until the required elongation or shaping has been achieved. Hydraulic presses are free from the vibration troubles of the steam and drop hammers, but are extensive installations. The pumping equipments and pressure reservoirs occupy much valuable space and make the entire equipment extremely expensive.

The requirements of the motor-car industry have led to the rapid progress in closed-die design and drop-forging technique. Dies have changed from simple impressions to multi-cavities with edging, fullering and blocking impressions incorporated in the same block. This has necessitated improvements in hammer equipment, particularly in the design of standards and methods of guiding. Off-centre impressions result in appreciable side thrusts and, consequently, the rate of slide wear is correspondingly higher.

Die blocks

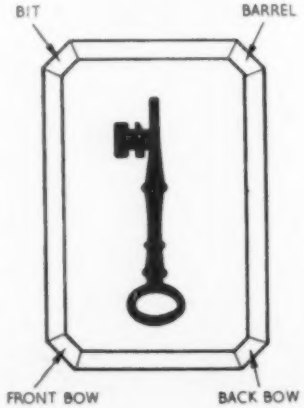
The importance of good die blocks cannot be over-estimated. The requirements of a die block are that it shall withstand the heavy and repeated impact of the forging blow, it must resist wear due to the abrasive nature of the scale and friction in areas of very heavy contact pressure, it must withstand thermal shock and must be capable of being machined. The making of die blocks is a specialized field of steelmaking and of forgemastering.

Modern die blocks are of several compositions and are forged to produce optimum strength conditions, after which they are heat-treated to several ranges of hardness. The choice of hardness in use depends upon many factors, particularly the depth of the impression and its shape. Most die sinking is carried out on the heat-treated blocks, as subsequent hardening introduces such hazards as cracking and dimensional distortion.

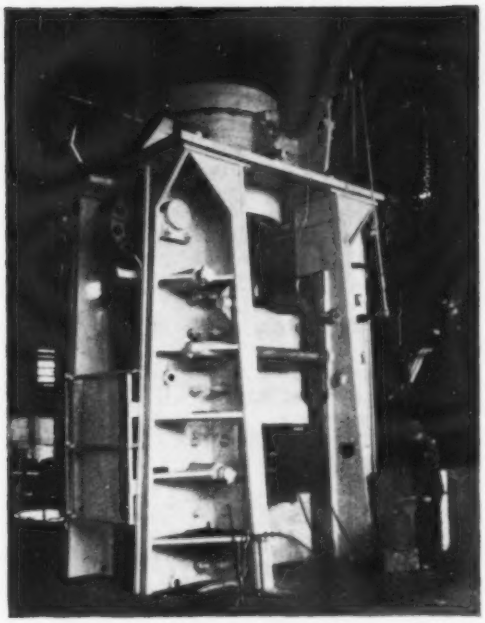
Die blocks are large when compared with the forged component, mass round the impression being required for two main purposes. The bursting stresses in the block can be very high, particularly on deep-pocket-type impressions. Apart from this, dies used for long runs can be repaired and maintained by re-sinking the impression, thus saving the cost of new dies when wear has reached a maximum on certain dimensions.

Die sinking

Die sinking is an art of its own. The blocks are



6 *Diagram showing naming of poppet pins from early key dies*



Smith-Clayton Forge Ltd.

7 *20-ton opposed-blow Beche hammer*

squared up for location and marked out by hand. Rough sinking is done in various ways, either by conventional end milling or by the more specialized copying die-sinking machines such as the Nassovia, Deckel or Hydrotel. Copy die-sinking either utilizes templates of the contour of a given plane or by wood, resin or metal masters which are systematically traversed by a stylus which transfers the motion through a pantograph linkage to a cutting tool.

Despite the great advances made with such specialized die-sinking equipment, the dies have to be hand finished, after which they are ' proved ' by casting lead impressions. All impressions have to make allowances for the contraction shrinkage of the forging on cooling.

The design must also incorporate facilities for the escape of the excess metal called ' flash,' and yet must permit maintenance of close tolerances in the forgings produced consecutively from the die. Die design is a highly skilled job, experience being the only qualification for success. Dies are expensive to produce and mistakes are costly. Without correct design, the correct flow of metal cannot be obtained and folds and cracks will be the result.

When the top and bottom impressions are finished, they are fixed in position on the tup and the anvil or bolster of the hammer.

Fixing locations on hammers are of two main types. When dovetail fixing is used the blocks are keyed in position with wedges. The other main method is by the use of ' poppets.' ' Poppets ' are screws of fairly massive proportions. There are four contained in pillars which are securely mounted on the anvil and so placed that each corner of a rectangular die block can be fixed. This allows for universal movement of the die block to obtain a correct register with the top impression. It is interesting to note that the four poppets on a hammer are still sometimes known as the barrel, the key, front bow and back bow. These relate to the corners of early key dies in the lock industry, each being named after part of the key (fig. 6).

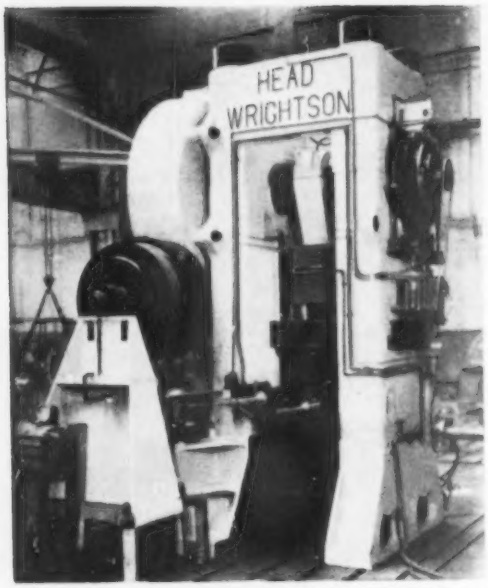
Types of drop hammer

Three main types of hammer are in common use today, namely the friction-belt hammer, the board hammer and the double-acting steam hammer. These vary in capacity from 5 cwt. to 20 tons, this referring to the weight of the tup itself, that is the falling mass. In the case of free-falling hammers, terminal velocities are of the order of 26—28 ft./sec., whereas the velocity of steam or air-actuated hammers is higher. There are many different designs of hammers, particularly of power-operated types.

An interesting development of relatively recent origin is the counter-blow German hammer known as the ' Beche.' This hammer is arranged so that the falling tup lifts the bottom anvil and die an equal distance, thus increasing the velocity at the point of impact. Apart from this advantage, the energy of the blow is more readily absorbed, which results in the necessity of smaller foundations and, consequently, less transmission of vibration. This type of hammer is limited to some extent in its use, being no good for ' off-the-bar ' work (fig. 7).

Board hammers are preferred for long-run work where fixed-stroke forging is possible. Although the length of fall on a board hammer can be predetermined, it cannot be altered during the forging cycle. Belt or steam hammers, on the other hand, can be varied in stroke blow to blow at the will of the driver and are thus preferred for certain types of work.

The more precise technique of closed-die drop forging has required a simultaneous development of other equipment, without which the hammer would be virtually useless. Die forgings can be made either ' off the bar ' or from slugs cut from billet or bar. These have to be heated to forging temperature in furnaces situated closely adjacent to the hammer. These were often crude affairs, frequently being fuelled with coke or coal.



Head Wrightson Machine Co. Ltd.

8 *Modern billet shearing press*

Heating for forging

Forge furnaces must be capable of operating for long periods at insulation temperatures up to 1,450 C. Furthermore, each hammer or press needs its own furnace as part of the production unit, as it is not usually convenient to serve more than one modern hammer with one furnace.

There are two main types of furnace, the slot-type for bar heating and the batch type for slugs, billet and 'use' heating. They are usually very simple in design and are relatively inefficient as a result of heat losses for several reasons, the main one being the difficulty in fitting doors, particularly on slot-type furnaces. Oil firing is usual, using fuels ranging in viscosity from 40 sec. to 900 sec. Various types of burners are in use, some of which are self-proportioning of the air supply.

Where production warrants the outlay, more complex rotary and pusher-type furnaces are finding a place, as are induction generators, the latter particularly in conjunction with press work.

When it is necessary to cut pieces or slugs from a bar prior to heating for forging, cropping or shearing equipment is required. This operation is not by any means as simple as it may appear at first sight. The condition of the cut ends, particularly from the point of view of squareness, is very important, particularly where they are to be used for press forging. Fraize must be avoided wherever possible for similar reasons. Mild steel in particular, that is the more ductile type of material, is not easy to shear without end distortion and therefore the utmost amount of maintenance of shear blades must be undertaken if consistent quality is to be achieved.

In the case of alloy steels there is yet a further difficulty. Under circumstances which are not clearly understood, alloy steels can crack seriously when cold sheared and it is necessary on occasions to warm up the stock by 100 or 200 C. so that the shearing operation may be carried out on the warm material.

Modern billet shears are efficient pieces of equipment designed to obviate as far as possible these types of defect. Because of the difficulties described, however, it is sometimes preferred to cold saw, which, unfortunately, is a much more expensive operation.

Apart from these adjuncts to the process, the flash unavoidably associated with the forging has to be removed.

Clipping

Clipping tools are designed to push the forging through a cropper while supporting the flash in such manner that shear occurs through the thickness of the flash as closely adjacent to the forging as possible. Most clipping is carried out immediately after forging, that is whilst the mass is at a high temperature. Cold clipping is also carried out in certain circumstances but is prone to objectionable cracking, particularly if non-metallic constituents have been forced into the flash during forging.

Clipping is usually carried out on conventional crank or eccentric presses of varying capacity, the latter often being dictated by the plan dimensions of the forging itself. Efficient clipping is important, as only by care and correct design of the tools can dimensions be maintained without further fettling.

Mechanical hammers have slowly developed from the early trip hammers, a development periodically stimulated as new sources of power were harnessed. As will be discussed later, the modern upsetter is the modern version of the early bolt-heading machine. Likewise, the forging press has undergone a parallel development. Early investigators must have considered crank, steam and hydraulic presses until the modern press was evolved, a piece of equipment still under active improvement.

to be continued

References

(1) Naujoks and Fabel, 'Forging Handbook,' 1953.
(2) N. Livingstone-Learmonth, *Geographical Magazine*, Oct. 1958, **31** (6), 296.
(3) K. Lange, *Metal Treatment*, Feb. 1951, **18** (65), 86-87.
(4) R. Butler, 'The History of Kirkstall Forge,' 1945.
(5) Naujoks, 'Fundamentals of Forging Practice.'
(6) Schofield, *Iron and Steel*, 1958, **31** (10), 452.
(7) F. J. Somers, *Metal Treatment*, Aug. 1953, 369-375.
(8) Guinness Book of Records.

Use of the electron microscope

Study of creep in a chromium-molybdenum steel

K. F. HALE, B.Sc., Grad.Inst.P.

This article is the second of a short series by different authors on the subject of electron microscopy applied to metallurgy. Last month's review discussed general principles and techniques of the electron microscope, and in the present contribution, Mr. Hale shows how a transmission electron microscope helped to make short duration tests possible in creep studies of a chromium-molybdenum steel. The author is with the Metallurgy Division, National Physical Laboratory

PRESENT-DAY POWER PLANTS require materials that can withstand stresses at elevated temperatures for times of the order of 100,000 hours. Naturally it would be highly desirable to predict the behaviour of these materials over long periods from tests of short duration. If the view is correct that creep strength is largely determined by the fine-scale microstructure, this would be possible if similar changes take place at different temperatures. The present work was done in an attempt to test this hypothesis, changes in microstructure in fairly long tests at service temperatures being compared with those occurring during shorter tests at higher temperatures. It was considered that the application of electron microscopy might make such short duration tests feasible.

The transmission electron microscope which was used to observe the fine scale microstructures is one of the best available today, and has a range of magnification between about 200 times and 200,000 times. The resulting power of this electron microscope is about 8—10Å (10Å = 10^{-7} cm.), which means that fine detail in the specimen with a separation of this amount may just be resolved. This resolution may be contrasted with that of the best optical microscopes, which have a corresponding figure of only 2,000Å.* In addition to this ability to see fine detail of molecular dimensions, the electron microscope has another advantage over the optical microscope in that it has a large depth of field which allows detail in the object several microns deep to be seen completely in focus, even at high magnifications. (One micron = 10^{-4} cm.)

The 2¼% Cr, 1% Mo steel, a typical superheater and steam-pipe power plant material, was chosen for study because suitable specimens were available from the work of Smith, Jenkinson, Armstrong and Day.[1]

Previous electron microscopical studies

The 2¼% Cr, 1% Mo steel has been studied with the electron microscope by several workers. Habraken[2] examined the changes in microstructure during tempering at temperatures of 400°C. to 830°C., also after creep tests conducted at 550°C. and at stresses ranging from about 2 to 13 tons/sq.in. for periods up to 6,500 hours. He found an intermediate phase rich in molybdenum and carbon. It appeared, during tempering at 550°C., in the form of plates and needles and grew on the (100) planes of the ferrite matrix in the [110] direction. It redissolved slowly at 550°C. and was replaced by the carbide $(M_1Mo_2)C$, *i.e.* M_6C. The process was similar, but very much more rapid, at 700°C.

Schrader, Rose, Rademacher and Pitsch[3] studied the carbides formed during tempering. They found a large amount of precipitate consisting of needles and platelets of irregular shape which they identified by electron diffraction as M_6C. This precipitate occurred at an early stage in the tempering as well as later on, as Habraken[2] found. They also observed pearlite areas consisting of

* The electron microscope is similar in principle to an optical microscope, but small wavelength electrons ($\lambda \approx 0{\cdot}05$Å) replace visible light ($\lambda \approx 5{,}000$ Å) and magnetic fields replace glass lenses. The final image is formed on a fluorescent screen, or may be photographed by replacing this screen with a photographic plate.

individual thin laths or bundles of laths which were identified as $M_{23}C_6$.

Baker and Nutting[4] studied a specimen that had been tested in creep at 550°C. at a stress of 17 tons/sq. in. for 4,172 hours (0·54% strain). No differences were found between the stressed and unstressed portions of the specimen. They also observed the formation of carbides with a Cr_7C_3 type of structure, and Mo_2C needles during tempering.

Smith and Nutting[5] also studied this Cr-Mo steel during tempering. They observed in specimens tempered at 650°C., 700°C. and 750°C., large carbide particles at the grain boundaries and small acicular particles within the grains, giving rise to a Widmanstätten structure. They also thought the small acicular precipitates were a chromium-rich carbide based on Cr_7C_3. In addition they reported the presence of Mo_2C and Fe_3C precipitates.

Experimental work

The work involved the re-examination with the electron microscope of a series of 2¼% chromium, 1% molybdenum creep test specimens taken from superheater tubes in the annealed and furnace-cooled condition. The results of the creep tests and of examinations of the specimens with the optical microscope have been published.[1] In addition comparisons were made with unstressed specimens heated at the same temperatures and for the same times as the creep test specimens.

The creep curves for the steel at several temperatures under a stress of 2¼ tons/sq. in. are reproduced in fig. 1.

Observations were made on the size, shape and distribution of second-phase precipitates in the various specimens. In transmission electron microscopy it is desirable to reduce the thickness of the object to less than 1,000Å (0·1 micron), and if the inherent resolving power of the instrument is to be utilized the thickness should be about 100Å. The microstructure of alloy steels is conveniently studied by preparing replicas of the specimen surfaces, although actual thinning of the bulk material is at present under development and has indeed been carried out successfully in several instances, *e.g.* stainless steel. Three types of replicas were used in the work, *viz.* preshadowed carbon, direct carbon and the carbon extraction replicas.[6]

The preshadowed carbon replica is made by evaporating under vacuum a 10Å shadowing layer of Au-Pd at a known angle to the polished and lightly etched metal specimen. This is followed by evaporating a 100Å backing layer of carbon normal to the specimen. The replica may be stripped from the metal specimen, provided that a very thin layer of hydrophilic substance separates the metal specimen from actual contact with the replica. The replica is self-supporting when mounted on specially prepared copper grids which have many square holes only 70 microns across in them. This replica when viewed with the electron microscope shows the precipitates as rocks on a sunlit landscape and, by measuring the lengths of the shadows, it is possible to determine the dimensions of structural details. Micrographs produced from these replicas are easy to interpret, but the resolution obtainable is only about 50Å due to the hydrophilic substance and aggregation of the shadowing material.

Higher-resolution direct-carbon replicas (resolution about 20Å) are prepared by evaporating under vacuum a 100Å thickness of carbon on to the metal specimen. Since no hydrophilic material is used the carbon replicas can only be stripped by dissolving the surface of the metal specimen away. Micrographs obtained from such replicas are a little more difficult to interpret than those obtained by the previous replica technique.

The carbon extraction replica is prepared in a similar fashion to the direct carbon replica, but is stripped from the metal specimen by dissolving the matrix, leaving the precipitated phases unattacked. This method, which proved to be the most useful, allows the actual precipitates to be seen, since they are attached *in situ* to the carbon film, and has the further advantage that X-ray and electron diffraction analyses may be carried out on these extracted phases.

An estimate of the mean distance between particles was made from extraction micrographs assuming that the precipitates on the extraction

1 *Creep curves at temperatures between* 550 *and* 650°C. *at* 2¼ *tons/sq. in.,* 2¼% *Cr,* 1% *Mo superheater tube*
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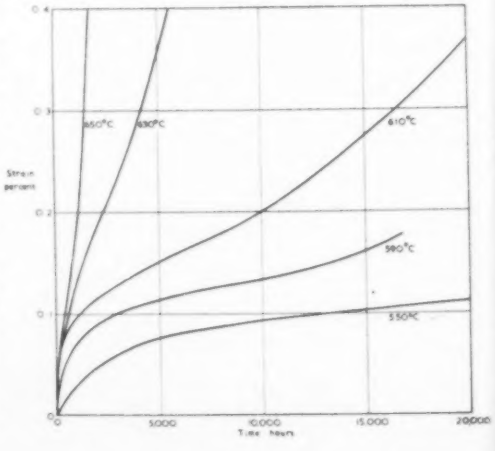
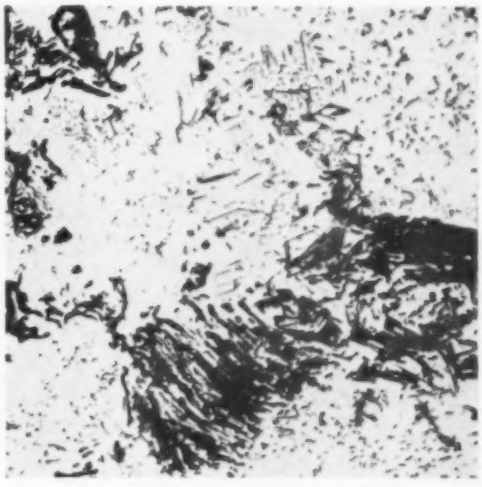


replica all intersected the original plane of polish of the specimen, and therefore that the number of precipitates which were caught up on the replica during processing and which did not intersect this plane was negligible. When the average number of particles per unit area was determined from the extraction micrograph, the square root of this quantity gave the average number of particles intersecting unit length in the given plane, and hence the mean distance between them. The results from extraction replicas were compared with those obtained from corresponding direct replicas, and were found to agree within experimental limits of about $\pm 20\%$.

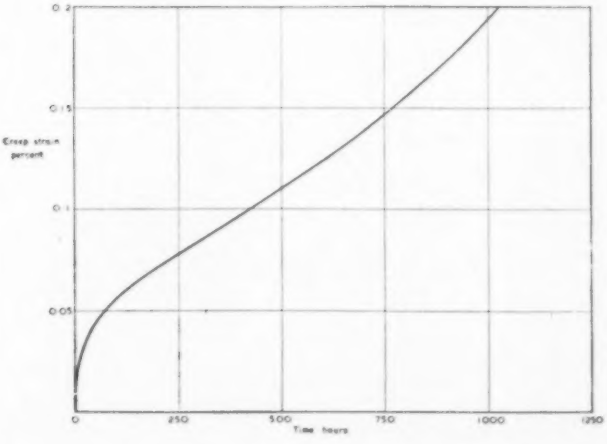
Experimental results

The general distribution of precipitate before creep or tempering can be seen from the carbon extraction micrograph of the 'as-received' structure at $\times 3{,}000$ (fig. 2). The microstructure consists of a relatively coarse precipitate, mainly in the shape of laths, several microns long, about 1,000Å across and several hundred Ångstroms thick, which occur in pearlitic clumps. In addition there are smaller acicular and plate-like types of precipitate which occur between the pearlite areas. The acicular precipitates are usually less than one micron in length, up to 400Å wide and 200Å thick, and the plate-like precipitates are about 1,000—2,000Å across. Since the pearlite areas occupy only approximately 20% of the volume of the material and are relatively stable compared with the finer precipitate in the ferrite areas, greater consideration was given to the latter. Fig. 3 shows these precipitates at $\times 25{,}000$. The mean distance between these particles was found to be about 0·33 micron.

The microstructures of the specimens creep tested at 650°C. will now be described. The corresponding creep curve for a stress of $2\frac{1}{4}$ tons/sq. in. is shown in fig. 4. Observations on 18, 30 and 100-hour specimens, 0·03%, 0·04% and 0·06% strain respectively, show that with increasing strain the finer needle precipitates become shorter and thinner, and the coarser needles become larger, presumably growing at the expense of the fine needles. The 300-hour specimen, 0·08% strain (fig. 5), shows the same trend, the microstructure being coarser than in the initial condition, and this trend is continued in the 1,000-hour specimen, 0·19% strain (fig. 6). After 1,000 hours, very few fine needles are seen, and the mean distance between particles has increased to about 0·5



2 ABOVE *Initial structure of* $2\frac{1}{4}\%$ *Cr*, 1% *Mo superheater tube. Carbon extraction replica* $\times 3{,}000$



4 LEFT *Creep curve for* $2\frac{1}{4}\%$ *Cr*, 1% *Mo steel at 650° C. at* $2\frac{1}{4}$ *tons/sq. in.*

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3 *Initial structure. Carbon extraction replica* × 25,000

5 *After* 300 *hrs. at* 650 *C. at* 2½ *tons sq. in.* 0·08% *strain. Carbon extraction replica* × 25,000

6 *After* 1,000 *hrs. at* 650 *C. at* 2½ *tons sq. in.* 0·19% *strain. Carbon extraction replica* × 25,000

7 *After* 5,000 *hrs. at* 650 *C. at* 2½ *tons sq. in. Ruptured at* 31% *strain. Carbon extraction replica* × 25,000

8 *After* 100 *hrs. at* 650 *C. at* 2½ *tons sq. in.* 0·06% *strain. Carbon extraction replica* × 25,000

9 *After* 100 *hrs. at* 650 *C. unstressed. Carbon extraction replica* × 25,000

10 *After* 1,000 *hrs. at* 650 *C. at* 2½ *tons sq. in.* 0·19% *strain. Carbon extraction replica* × 25,000

11 *After* 1,000 *hrs. at* 650 *C. unstressed. Carbon extraction replica* × 25,000

12 *After* 5,000 *hrs. at* 650 *C. at* 2½ *tons sq. in. Ruptured at* 31% *strain. Preshadowed carbon replica* × 25,000

13 *After* 5,000 *hrs. at* 650 *C. unstressed. Preshadowed carbon replica* × 25,000

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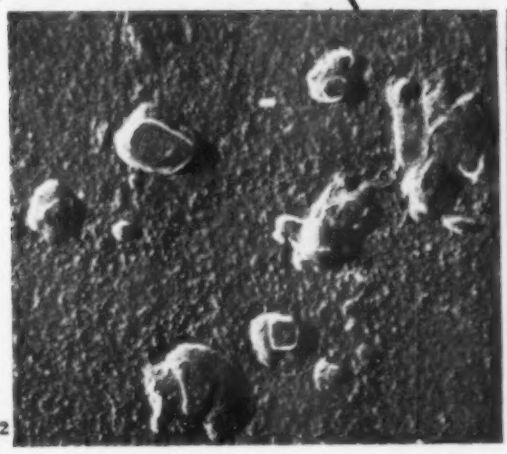

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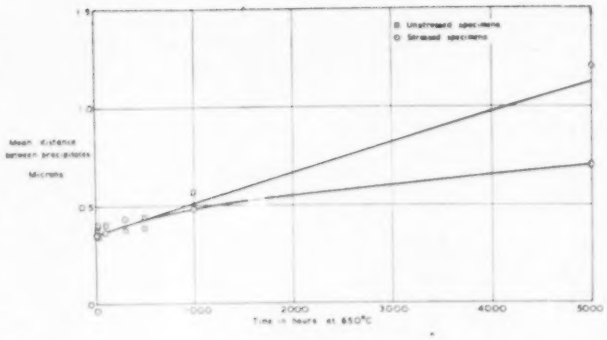

14 RIGHT *Change in mean distance between precipitates with time at 650°C. for stressed (2¼ tons/sq. in.) and unstressed specimens*

15 BELOW *Temperature-log time diagram for specific creep strains at 2¼ tons/sq. in. 2¼% Cr, 1% Mo superheater tube*

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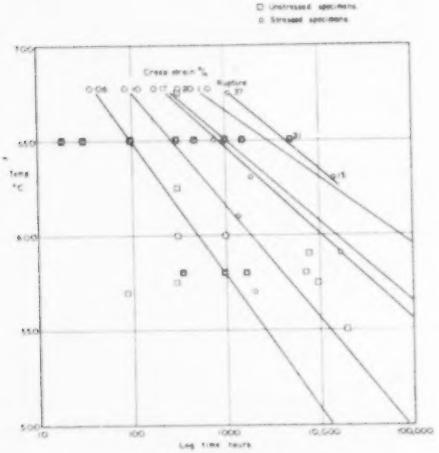

micron. It is seen from the creep curve (fig. 4) that the tertiary stage of creep has begun.

A specimen which represents a continuation of the series to its logical conclusion ruptured at a strain of 31% after 4,890 hours at 650°C. (fig. 7). Considerable coarsening of both the pearlitic type of precipitate and the smaller precipitate has occurred and the mean distance between the particles has now increased to more than a micron.

The corresponding set of unstressed specimens that had been subjected to a temperature of 650°C. for the same times as the creep specimens showed no differences from the latter in the sequence of change in the precipitate microstructure up to 1,000 hours. However, a pair treated for 5,000 hours at 650°C., which represented a difference in strain of 31%, showed that the spheroidization of the precipitate had proceeded to a more advanced stage in the case of the 2¼ tons/sq. in. stressed specimen, compared with the unstressed one. The mean distances between precipitates were 1·2 microns and 0·7 micron respectively. It may be concluded that during secondary creep at 650°C., at stresses of up to 2¼ tons/sq. in., that is, at strains of up to 0·2%, the changes in the size, shape and distribution of the precipitates proceed in the same way and at the same rate as in tempering at the same temperature. However, during the tertiary stage of creep leading to rupture, there is an increase in the rate of spheroidization compared with the unstressed condition. These conclusions are illustrated in figs. 8 to 13. Curves showing the changes in mean distance between precipitates with time at 650°C. for stressed and unstressed specimens are shown in fig. 14.

In their paper Smith *et al.*[1] showed a graph where specific creep strains are plotted on a temperature-log time diagram, and this graph is reproduced in fig. 15. By plotting on this graph specimens that had been examined, it soon became evident that specimens had the same microstructure for the same strain, irrespective of test temperature. This meant also that a similar sequence of events took place over a wide range of temperatures. To illustrate this, micrographs (figs. 16—21) are shown of three pairs of stressed specimens which had similar amounts of strain, *viz.* 0·06%, 0·19% and

16 *After 1,000 hrs. at 580°C. at 2¼ tons/sq. in. 0·06% strain. Carbon extraction replica* × 25,000

17 *After 100 hrs. at 650°C. at 2¼ tons/sq. in. 0·06% strain. Carbon extraction replica* × 25,000

18 *After 17,000 hrs. at 590°C. at 2¼ tons/sq. in. 0·18% strain. Carbon extraction replica* × 25,000

19 *After 1,000 hrs. at 650°C. at 2¼ tons/sq. in. 0·19% strain. Carbon extraction replica* × 25,000

20 *After 13,000 hrs. at 630°C. at 2¼ tons/sq. in. Ruptured at 15% strain. Preshadowed carbon replica* × 25,000

21 *After 1,000 hrs. at 675°C. at 2¼ tons/sq. in. Ruptured at 37% strain. Preshadowed carbon replica* × 25,000

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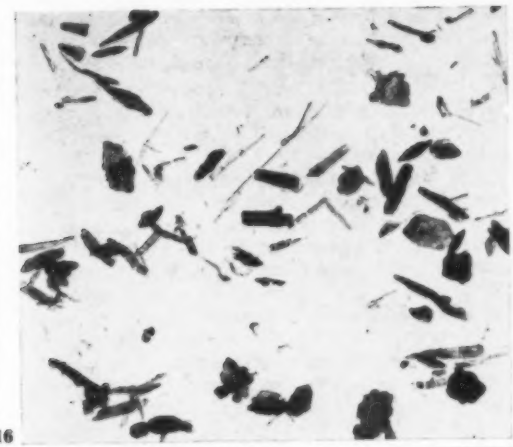

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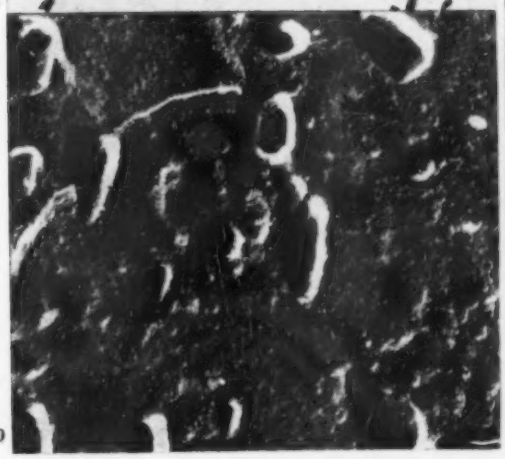

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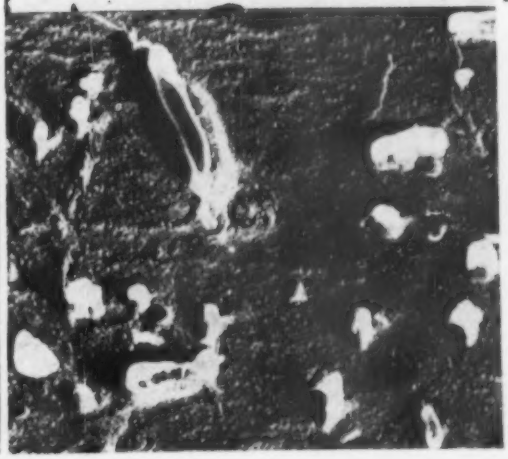

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rupture, but had received different creep treatments. These conclusions are also consistent with the measurements of the mean distance between particles. Results for all the specimens subjected to creep tests are plotted against strain in fig. 22. The spacing begins to increase perceptibly at about 5 % strain and, as far as the results go, the subsequent increase is independent of test temperature; it depends only on the strain reached.

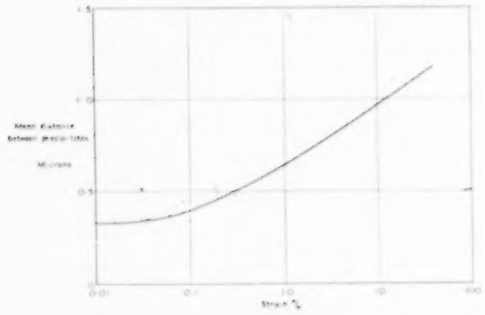
Identification of precipitates

Identification of the precipitates in the extraction replicas by electron diffraction examination of selected areas in the electron microscope has been attempted. Electron diffraction examination is carried out quite simply by reducing the strength of the intermediate lens so that it now images the back focal plane of the objective lens, where a diffraction pattern of the object is formed. The enlarged image of the diffraction pattern consists of bright spots and rings and, by measuring the positions and intensities of such details, it is possible, in principle, to determine the size, shape and orientation of the unit cell which makes up the atomic lattice of the object and hence in this case to determine the chemical composition of the various minor phases which occur in the steel.

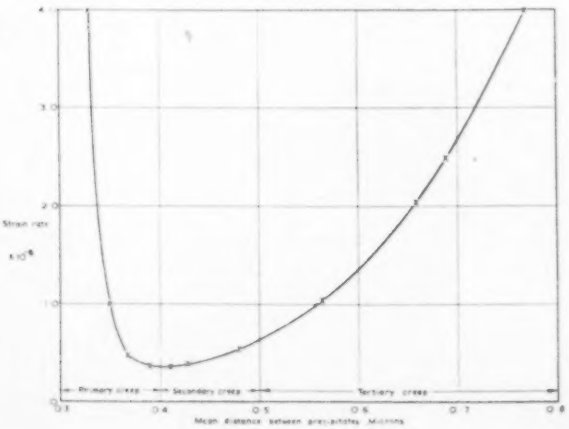
Accurate identification was made difficult because gradual transitions from one carbide to another took place by changes in the iron, chromium and molybdenum compositions, and hence the interplanar spacings did not agree absolutely with listed spacings of particular carbides. Reasonably clear ring patterns were obtained from the acicular carbide in the ferrite areas, and both fine and coarse needles were found to be M_2C, where M represents Fe, Cr and Mo, with lattice spacings some 4% smaller than those of Mo_2C. This is consistent with the fact that a considerable portion of M is probably made up of iron and chromium, both of which have smaller atomic sizes, and hence would decrease the size of the Mo_2C lattice.

The lamellar precipitates in the pearlite areas gave rather spotty electron diffraction patterns, but it was possible to confirm previous X-ray work on these specimens by Smith *et al.*[1] that they were $M_{23}C_6$, where M represents Fe, Cr and Mo.

It was not possible to identify the coarser precipitates by electron diffraction. However, X-ray diffraction work showed that the amount of M_6C precipitate present in the creep specimens increased with increase in strain and that there was no M_6C present in the 'as-received' specimens. Thus, when the 2¼% Cr, 1% Mo steel goes into service, it contains $M_{23}C_6$ laths in pearlitic areas, with M_2C needles in between, but during service the M_2C needles disappear and finally $M_{23}C_6$ and M_6C spheroidized precipitates are obtained. Smith *et al.*[1] show from chemical analyses of extracted residues that the derived value of the molybdenum content of the matrix is reduced from 0·6% initially to 0·3% at the time of rupture in a 630° C. creep test,



22 ABOVE *Change in mean distance between precipitates with increasing strain for creep tests at temperatures between 750 and 650° C.*



23 RIGHT *Strain rate during creep test at 650° C. plotted against mean distance between precipitates*

Crown copyright. Courtesy of the National Physical Laboratory

and the molybdenum content in the carbides has increased from about 0·45% to 0·6%, whereas the iron content has remained more or less constant. It can be further deduced from their data that the increase in the amount of carbide precipitated in the matrix during the course of creep to rupture is of the order of 15%. Much of this increase is supplied by molybdenum coming out of solution.

Backgrounds in micrographs

In all micrographs a background effect was observed. After extensive work to determine the cause, including reduction of contamination during preparation of the replicas, it was concluded that the backgrounds could be interpreted as an etching effect, possibly due to Zener[7] platelets. The effect was more pronounced in electro-polished than in mechanically polished specimens.

Discussion

It is now generally recognized that finely dispersed precipitates are one of the factors which lead to good creep resistance of an alloy. It is thought that, prior to the creep test, dislocations are distributed throughout the matrix of the material, and that when a stress is applied they tend to move but are stopped by obstacles, which in the case of alloys include precipitates. Ease of climb of the dislocations over the precipitate obstacles will depend on several factors, including size, shape, distribution and coherency of the precipitates, and it is very probable that finely divided and closely spaced needle precipitates will be more effective in hindering the movement of dislocations than will widely spaced coarse spherical ones.

By comparing the microstructures of the creep specimens with their positions on the creep curves, it appears in the case of the 2¼% Cr, 1% Mo steel that, whilst secondary creep continues, there are some fine needle precipitates in the matrix, and that the mean distance between precipitates does not exceed 0·5 micron. After this the tertiary stage of creep begins and rupture takes place when the mean distance between spheroidal particles is about 1·2 microns. This is compatible with the observation that, for strains up to 0·2% at least, the changes in precipitate microstructure are apparently independent of whether a stress is applied or not and therefore it is possible to suggest that the actual creep rate at any time may be a function of the state of the precipitate microstructure at that time. It is tempting to think that the increase in creep rate above about 0·1% (fig. 1) is due to this increase in particle spacing. When the variation in creep rate with time at 650°C. is plotted against the corresponding change in distance between particles (fig. 23), it seems that the increase in creep rate beyond about 1×10^{-8}/sec. is too large to be accounted for by the increase in particle spacing. This suggests that the changes which occur in the matrix are also important.

This investigation has been mainly concerned with precipitation hardening, but solid solution strengthening, although undoubtedly playing a part in the change in creep resistance during service, should make no difference to the preceding arguments since the two processes are inter-related.

From this work, it seems possible to equate time and temperature for a given stress and strain for temperatures between 550°C. and 650°C., thus providing the possibility of comparing a relatively short duration creep test at 650°C., with a relatively long one at 565°C., the service temperature. The consequent gain in time is a factor of about 100: 1.

Since there is an apparent correlation between the amount of strain undergone by the Cr-Mo steel and the precipitate microstructure, it might be possible to make an estimate of the stage in creep life reached by actual power plant components, by taking specimens at times of overhauls. This assumes, of course, that the stresses induced in power plants do not exceed 2½ tons/sq. in., since the effect at higher stresses has not been studied.

Conclusions

Observations have been made on specimens covering stressed (2½ tons/sq. in.) and unstressed conditions between 550°C. and 675°C. and times up to 20,000 hours. Four main conclusions are drawn:

1. Specimens, stressed or unstressed, subjected to the same temperature for the same time have similar microstructures, providing the tertiary stage of creep has not been reached.

2. Stressed specimens with the same strain have similar microstructures for creep tests conducted between 580°C. and 650°C.; creep specimens at 580°C. and 650°C. have a creep test time ratio of the order of 10: 1.

3. At the commencement of creep there is a fine needle precipitate which gradually disappears during secondary creep and is replaced by a more widely spaced coarser precipitate. During the tertiary stage the precipitate spheroidizes and the mean distance between particles increases.

4. In this particular steel it appears that changes in the matrix composition during creep as well as changes in the precipitates have a significant effect on the creep strength.

Conclusion 2 suggests the possibility that, in materials where there are no sudden transformations

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Microscopes

Modern design of optical equipment

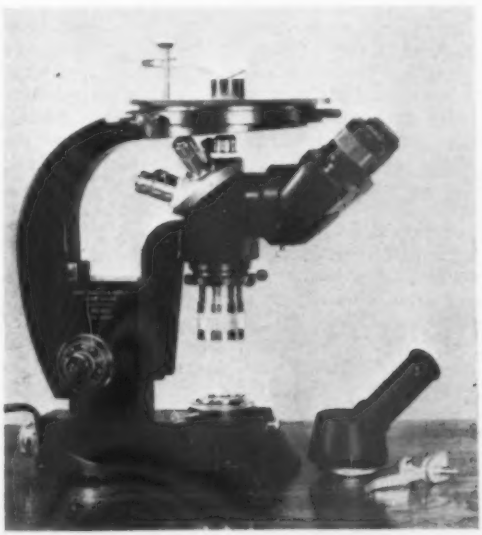
Recent trends in the design of optical equipment intended for metallurgical applications have resulted in some notable advances in available techniques. This short review deals chiefly with optical methods of examining minute irregularities of metal surfaces

RADICAL CHANGES in microscope design are necessarily rare, and the principle of the inverted specimen metallograph with the specimen held face downward on the stage and illuminated from below was introduced by Le Chatelier as long ago as 1901. The method has proved very time-saving, particularly in routine investigations, as mounting, levelling, and possible damage to the specimen is avoided.

Two high-quality bench microscopes constructed on the Le Chatelier principle, with built-in illumination and comfortably operated stage and focusing control, are shown in figs. 1 and 2. The British-made instrument illustrated in fig. 1 is the Cooke inverted microscope introduced by Cooke, Troughton & Simms Ltd., and the schematic diagram (fig. 2) shows a German instrument of this type—the Carl Zeiss standard metal microscope.

Both microscopes are built on modern lines, stable and simple in outline, and designed for maximum comfort and efficiency. The low position of the coarse and fine focusing controls on a common axis, and the gliding object stage which may be readily displaced in any desired direction are admirable aids to operator comfort. These instruments are available with monocular or binocular viewers and are fitted with quintuple revolving nosepieces for rapid objective changing without the need for coarse refocusing. The built-in illumination, situated in the base, consists of a 6-V., 15-W. lamp necessitating the use of a transformer when running on mains supply. The sturdy build of these instruments permits their use on the shop floor and they are primarily intended for routine examinations and production control. Nevertheless, cameras are available for photographic recording, and these instruments could be useful in applications where the larger and more expensive metallographs are felt to be too elaborate.

An inverted microscope of novel design is the Cooke-McArthur miniature microscope which was described in this journal in July, 1958. The radical reduction in the dimensions of this instrument is achieved by reflecting the optical path twice through 90 deg. by means of two prisms, thus allowing the whole system to be arranged in a small rectangular box which may be held in the hand during use (fig. 3). The instrument was developed in the first instance for medical work, but the addition of an incident illuminator has now made it available as a metallurgical microscope with the advantage of extreme portability. We hope to publish a more detailed account of the potential metallurgical uses of this microscope in a future issue.



1 *Cooke inverted microscope*

Automatic profile milling

DELIVERY of what is claimed to be the world's first magnetic-tape-controlled airframe profile milling machine to Lockheed Aircraft Corporation, Burbank, California, has been made by Giddings & Lewis Machine Tool Co., designers and builders of the equipment.

The Lockheed machine also represents the first production model of a new family of G. & L. variable-axis-control, profile airframe milling machines (Variax). Airframe designs often involve profiles derived from loft data, generated step cuts, continuously variable angles, pocket and multiple recess milling, internal variable angles, and machine control governed by element line geometry, operations completely out of the question for conventional milling machines.

Movements of the 'Variax' machines are derived from a combination of (1) horizontal movement of the column upon its runway and (2) vertical movement of the saddle on its column ways for 360-deg. path control in the plane of the angle plate where the work is mounted. In addition, the company's five-axis machines provide (3) depth motion through movement of the head along the spindle axis, (4) head swivelling in the saddle plane on segmental ways to achieve a transverse tilt function and (5) column swivelling, on an axis coincident with the extension of the cutter centre line, to give longitudinal tilt, making up angular motions to the spindle that have a common locus point on the spindle axis. These provide a programming plane where zero movement of the cutter axis exists during angular displacements of the tool, eliminating corrections and compensations that would otherwise be necessary. On five-axis machines, all cutter-axis motions are infinitely variable and completely co-ordinated by a numerical system which gives continuous control of all movements.

Once the machine is orientated and its magnetic tape control system started, the Variax automatically positions to the correct cutter-entry point, proceeds at a predetermined feed rate, gauges the correct distance and form of cuts, and retracts at the conclusion of the sequence of operation.

With the G. & L. Numericord system, such operations as template setting and changing, positioning by manual operation, tool setting, and progressive gauging have been eliminated or radically reduced. Time and material losses resulting from wasted operator motion, lack of skill, miscalculations and human error are also eliminated.

Programming from part drawings

Machine-command computations are made directly off part drawings by procedures familiar to most engineering personnel. They work only with ordinary decimal, digital information in preparing manuscripts of time and distance commands necessary to advance cutters through the desired path configurations for each operational sequence. Transcribing data from programmers' manuscripts to perforated paper tape is readily accomplished with clerical help. This operation is simplified materially by use of a normal 10-digit keyboard and is safeguarded by logical circuitry which automatically checks the accuracy of all data fed into the perforating unit.

studies made by interferometry but is much more easily applied.

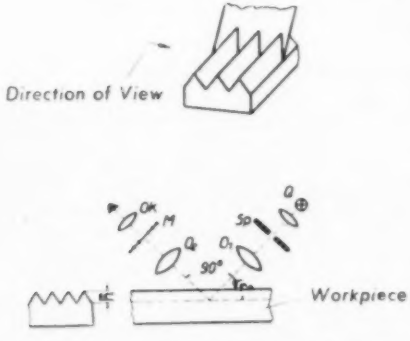
The additional equipment necessary to adapt the Vickers projection microscope for this work is a parallel line graticule which fits into the housing of the field iris and an auxiliary iris diaphragm which fits into the lamp condenser filter holder.

Light-section microscope

A new type of microscope made by Carl Zeiss, of Western Germany, employs the light-section method developed by Professor Schmaltz, and enables accurate measurement of surface ripples and grooves to be made (figs. 5 and 6).

The microscope combines an illumination and an observation microscope at right-angles to each other and at 45 deg. to the test-piece. In this way a 'profile' observation or photograph can be obtained. The instrument also contains a reticle, with a vertical and horizontal cross-line visible in the eye-piece. By operating the measuring drum, it is possible to obtain the depth of roughness by measuring the difference between the peak and the trough in the profile image utilizing the horizontal cross-line, and the distance between ripples or grooves by utilizing the vertical cross-line. The values may also be measured on a photograph.

The microscope is built with a newly developed nose-piece for objectives, consisting of two pairs of objectives with a microscope magnification (height of profile) of ×400 and ×200. The ×400 magnification permits measuring depths of roughness of 1-4μ, and the ×200 permits 3-100μ.

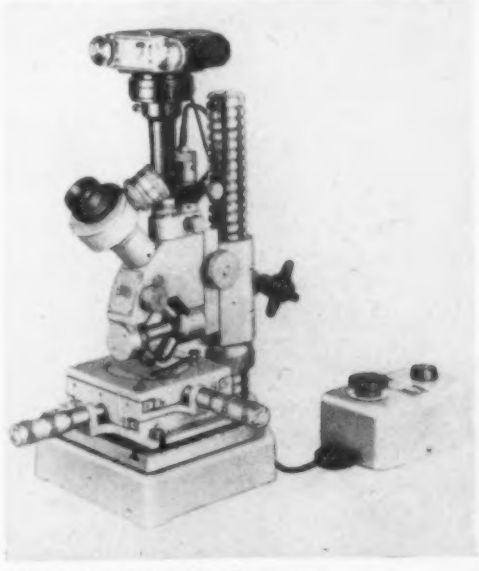


5 *Principle of the Zeiss light-section microscope. The incandescent lamp Q illuminates the slit Sp, which—by means of the objective O_1—is reproduced on the surface as a fine band of light. The band of light on the surface is observed with a microscope whose objective O_2 renders exactly the same magnification as the imaging objective O_1. A reticle M is visible in the eyepiece Ok, which may be shifted within the field of view by means of a measuring drum. At the measuring drum the measuring values may be read directly in μ. Illumination and observation microscopes are arranged at right-angles to each other. In relation to the surface of the production part they form an angle of 45 deg.*

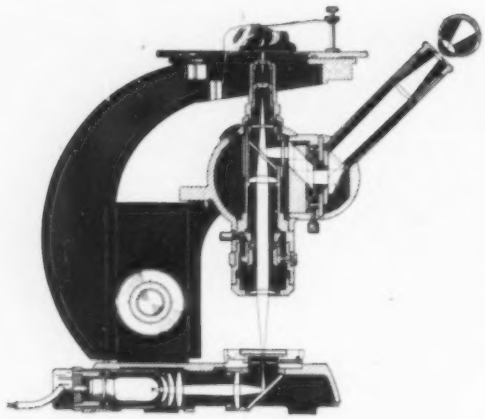
4 *Bright field method. Multiple profiles of a fine-finish diamond-turned soft aluminium bearing* × 1,000

Measurements of contours can be carried out vertically and horizontally *without* having to convert the readings on the measuring drum. With the ×400 magnification, one graduation of the measuring drum equals 0·5μ, while with the ×200 magnification one graduation equals 1μ at the object.

An added feature in the microscope is a centre cradle designed for the rotation and close examination of turned parts with centre openings up to a diameter of 60 mm. For other cylindrical work, a U-bearing on a mechanical stage is available.



6 *Carl Zeiss light-section microscope*



2 *Carl Zeiss standard metal microscope*

Surface-profile measurement

Studies of the minute irregularities of machined, ground or lapped metal surfaces may be made by a number of techniques. Although the high sensitivity of interferometric methods makes this technique indispensable in certain applications, there are many instances where a less sensitive method is required.

Some years ago Schmaltz described a method for detecting and evaluating small errors present in plane or cylindrical surfaces, and more recently Tolansky has evolved a method of the same order of sensitivity and greater convenience, which is very easily applied to the Vickers projection microscope (Cooke, Troughton & Simms Ltd.).

Originally, the method consisted of placing a slit close to the field iris of the microscope. The field lens formed a virtual image of this slit in a plane conjugate to that of the specimen, and an image of the slit was therefore formed on the surface of the specimen. If now the metal tongue reflector is substituted for the cover glass, an oblique image of the slit is thrown on to the specimen under test and, if irregularities are present in the surface, the edges of the slit image will no longer be straight. This is the ' light slit ' method.

Prof. Tolansky replaced the slit by either one or a series of wires or parallel straight lines ruled on glass, and this method has the advantage that the surface detail of the specimen can be seen, as well as the oblique images of the rulings. We now have a bright field crossed by dark lines instead of the reverse.

It is anticipated that this improved technique will have particular value for the examination of crystal surfaces, machined surfaces and the depth of hardness indentations. Fig. 4 shows a surface traversed by a number of profiles—it combines the advantages and ease of interpretation of line profilometers with those of area interferograms. The method is non-destructive, as no mark is left on the surface of the specimen, and it may be applied to plane or cylindrical surfaces.

The magnification in depth is determined by the use of a stepped slide formed by volatilization in a vacuum, the depth of step having been previously determined by means of fringes of equal chromatic order to be later described. Using a 2-mm. oil immersion objective, the magnifications in depth and in length are almost identical, so that the line profile picture exhibits little distortion and is very nearly a trule profile section. For exact quantitative work the deviations from a straight line of the edges of the slit image may be measured either by means of a filar micrometer inserted in the eyepiece tube or by scaling a photograph. The order of accuracy by the former method is $\lambda/2$ or 10 μin.

The obliquity produced by the tongue reflector is constant for any objective and it is, therefore, only necessary to determine its factor, once and for all, by means of the stepped slide. One can then select an objective of the required ' depth of focus ' and proceed to evaluate the surface irregularities with the aid of the known ' factor.'

Monochromatic light must be used, as the eccentric pencils are subject to colour fringes and a green filtered mercury source is admirable. Magnifications in excess of ×2,000 have been used and the procedure conveniently links up with

3 *The current version of the McArthur microscope was demonstrated for the first time in* 1955 *at a World Health Organization conference in the Philippines. Dr. John McArthur, the designer, is seen here (right) in an aircraft with several colleagues from the conference. Dr. John Field, until recently director of the Institute for Medical Research, Kuala Lumpur, is using the microscope. In spite of the vibration he was able to identify malarial parasites in a blood film*

X-ray measurement of textural stresses

At the U.S. National Bureau of Standards, a physicist adjusts the angle of incidence of X-ray beam upon a specimen of 2-phase brass. The X-ray beam emerges from the circular film holder in front of the specimen. The two phases are 'sorted out' by diffraction resulting in a pattern on the film. From such patterns microscopic stresses between the phases may be calculated

In recent experiments at the U.S. National Bureau of Standards, textural stresses in metals have been measured by means of X-rays. Results of experiments show the impossibility of obtaining a completely stress-free condition in metals which contain more than one phase. Consequently, textural stresses must be considered in investigations to determine the cause of corrosion, metal fatigue, and crack formations in metals used for industrial purposes. The data derived from this work should aid metallurgists in relating internal stresses to the mechanical and physical properties and behaviour of two-phase alloys

AMONG THE PROPERTIES of two-phase alloys which differ are the thermal expansion coefficients of the two phases. As a result, there is a tendency toward unequal changes in the volume of each phase as the metal cools from the liquid state. The unequal volume changes cause intergranular forces to arise which are known as textural stresses. These stresses are to be distinguished from the other type of internal stress occurring in metals known as body stresses, both of which have been thoroughly reviewed in the literature under several systems of nomenclature.

Brass and carbon steel specimens

In conducting the experiments, C. J. Newton and H. C. Vacher of the Bureau's mechanical metallurgy laboratory used annealed specimens of brasses and of carbon steel. Formulae for the approximate values of the principal stresses in the grains were obtained from a detailed theoretical analysis of textural stresses made by F. Laszlo. To avoid extraneous stresses, the surfaces of the metal specimens were carefully finished with many cycles of alternate mechanical polishing and electro-polishing.

Stress measurements were made by X-ray diffraction techniques which permit highly precise determination of the inter-atomic distances in crystals. When stresses arise, a regular change

TABLE I *Stresses in brass*

	Alpha brass		Beta brass	
	Strain	Stress (lb./sq. in.)	Strain	Stress (lb./sq. in.)
Two-phase	$-2{\cdot}58 \times 10^{-4}$	$-5{\cdot}27 \times 10^{3}$	$4{\cdot}47 \times 10^{-4}$	$6{\cdot}53 \times 10^{3}$
Single-phase	$-1{\cdot}39$	$-2{\cdot}83$		
	Precision in stress about $\pm 3{\cdot}2 \times 10^{3}$ lb./sq. in.			
	Theoretical values of stress			
Two-phase		$-4{\cdot}33$		$5{\cdot}33$

Scratch measurement

There are many industrial processes where it is necessary to measure the depth of irregularities in a fairly coarse surface and to have, at the same time, a picture of the shape of the irregularities which may be scratches, blisters, corrosion or just general superficial roughness. This type of surface is too rough to examine with an interference microscope and the manufacturer wants more information about superficial structure over an area than can be given by a stylus instrument. Hilger & Watts Ltd. have developed their scratch investigation microscope to serve this purpose (fig. 7).

The scratch investigation microscope throws the oblique shadow of the edge of a half-shade graticule on to the surface under examination and the amount of indentation in the edge of the shadow is read on a graticule in the eyepiece after magnification by a low-power microscope.

The microscope is placed on the surface so that the sharp edge of the shadow is at right-angles to the scratch under examination and, due to the oblique illumination, there will be an indentation in the shadow edge which will vary in depth with the depth of the scratch. A scale is provided in the field of view from which the depth of indentation and hence the depth of the scratch can be read off directly in thousandths of an inch (0·02 mm.) with a possibility of interpolating to fractions of this amount. By means of another scale, perpendicular to the first, the width of the scratch can also be measured.

7 *Hilger & Watts scratch investigation microscope*

8 *Taylor-Hobson turbine-blade-edge microscope*

Turbine-blade-edge investigation

A further example of the application of the light-slit principle may be seen in the turbine-blade-edge microscope developed by Taylor, Taylor & Hobson Ltd. for critically viewing the shape of the leading and trailing edges of turbine blades.

The microscope works on the light-slit principle. A narrow band of light is projected obliquely round the edge of the blade to delineate the section. This is viewed obliquely through the microscope. The elements of the microscope are so arranged that the obliquities cancel out. The image seen through the eyepiece is that of the normal cross-section of the blade.

The observed shape is compared with a master drawing prepared at ×20 size on a card which is slipped into a holder on the instrument. The card is seen through the eyepiece of ×2 magnification (making ×40 in all).

The brightness of the drawing image relative to the blade image is adjustable so as to accommodate for both dark and bright blades. Conveniently

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TABLE II *Stresses in steel*

Radiation	Bragg angle	Mass absorption coefficient	Pearlitic		Spheroidized		Decarburized		Probable error in the stress (lb./sq.in.)
			Strain	Stress (lb./sq.in.)	Strain	Stress (lb./sq.in.)	Strain	Stress (lb./sq.in.)	
Cobalt ..	81	54	3·99 × 10^{-4}	14·12 × 10^{3}	1·00 × 10^{-4}	3·56 × 10^{3}	0·16 × 10^{-4}	0·57 × 10^{3}	1·92 × 10^{3}
Iron ..	73	72	1·30	5·57	1·59	6·84	2·45	10·52	5·34
Chromium	78	115	4·20	14·38	3·18	10·89	2·72	9·29	2·02
Weighted average				12·74		6·05		4·58	2·53
Theoretical values				9·2		6·2			

occurs in the spacing of the atoms, and as the X-ray diffraction 'sorts out' the separate phases it is possible to measure these microscopic stresses if they affect one phase differently from another. An averaging of the tri-axial stress state over many grains of one phase results in a pseudo-hydrostatic stress. However, relaxation of the component normal to the exposed free surface results in a bi-axial state of stress whose average value can be measured by the well-known two-exposure X-ray method.

The observed relative lattice changes and the calculated values of the stresses for the brass specimens are presented in Table I. This table also shows the probable error in the stress measurement and the theoretical values of stress calculated for the two-phase brass. Table II gives the calculated values of the stresses for the steel specimens. The stresses observed ranged from −5,270 lb./sq. in. to +14,380 lb./sq. in. The probable error in measurement in most of the experiments was about 3,000 lb./sq. in. The measured values of the brass specimens agreed very well with the theoretical values of Laszlo, and those of the steel agreed to a qualitative degree.

This work experimentally validates Laszlo's theoretical analysis of textural stresses arising from inequalities of thermal expansion of micro-constituents. Also, the success of the experiments contradicts previously expressed opinion that such stresses could not be measured by X-rays. The only caution that has to be observed is careful surface preparation of the metal specimens to avoid extraneous results in the X-ray diffraction.

Bibliography

C. J. Newton and H. C. Vacher, 'An X-ray study of textural stresses in two-phase alloys,' *J. Research N.B.S.*, 1957, **59** (4), RP 2793.

E. Orowan, 'Classification and nomenclature of internal stresses,' Symposium on Internal Stresses in metals and alloys, *Inst. Met. Monograph and Report Series No.* 5, 1948, p. 47.

F. Laszlo, 'Tessellated Stresses,' Parts I-IV, *J. Iron & Steel Inst.*, 1943, **147**, 173; 1943, **148**, 137; 1944, **150**, 183; 1945, **152**, 207.

C. S. Barrett, 'Structure of Metals.' McGraw-Hill Book Co. Inc., 1952.

Use of the electron microscope

concluded from page 153

accelerated creep tests may be conducted at temperatures up to 100°C. above the intended service temperature, with time savings of at least 10 to 1.

References

(1) A. I. Smith, E. A. Jenkinson, D. J. Armstrong and M. F. Day: J/T 170. The Electrical Research Association, 1957, pp. 1-59. 'Steels for Use in Steam Power Plant Operating Above 950°F. Creep, Stress-Relaxation and Metallurgical Properties.' To be published in *Trans. A. Mech. E.*

(2) L. Habraken, Thèse d'Agregation de l'Enseignement Supérieur, Université de Liége, 1953. Publié par Centre National Recherches Métallurgiques.

(3) A. Schrader, A. Rose, L. Rademocher and W. Pitsch, *Arch. Eisenhuttenwesen*, Aug. 1957, **28**, 461-468.

(4) R. G. Baker and J. Nutting, BISRA Reports Nos. MG/J/101/55 and MG/J/248/55.

(5) E. Smith and J. Nutting, BISRA Report No. MG/J/251/55.

(6) E. Smith and J. Nutting, *Brit. J. Appl. Phys.*, 1956, **7**, 214-217.

(7) C. Zener, *Phys. Rev.*, 1948, **74**, 639.

(8) K. F. Hale, Proc. Int. Conf. Electron Microscopy, Berlin, 1958. In press.

Microscopes

concluded from page 158

placed adjusting screws permit the image to be quickly lined up with the drawing. Eyepiece graticules are not required. The resulting saving in operating cost and avoidance of delay should contribute greatly to the effectiveness of the instrument.

Blades up to 2½ in. (63·5 mm.) wide, and as long as desired, can be handled. The field of view at the blade edge is 0·18 in. (4·5 mm.) diameter. The shape of the blade edge is seen at a magnification of ×40. This makes errors of 0·001 in. (0·025 mm.) comfortably visible.

Blades up to about 8 in. (203 mm.) long are held against a V fitting by means of a spring plunger. Longer or very heavy blades may need to be held against the V fitting by hand.

Acknowledgments

Thanks are due to the manufacturers mentioned in this review for information and photographs.

F. D. GRIMMER

Cobalt

Although cobalt compounds have been known and used since early times, the metallic element has only been available in a suitable form as an alloying addition for high-speed steels since 1910. *This article, which is the third of a series on the newer metals appearing in this journal, is based on information given in 'Cobalt,' December,* 1958—*a new publication of the Centre d'Information du Cobalt, Brussels, Belgium*

SOME YEARS AGO IN EGYPT archaeologists discovered blue glass statuettes in tombs undisturbed for over 4,000 years. Spectrographic analysis of these objects has shown that a cobalt-base colouring agent was used by the ancient Egyptians. The secret of the manufacture of this glass seems to have been lost until the 16th century.

Around 1520, in Saxony, a blue pigment was produced from complex arsenical silver-cobalt-nickel-bismuth ores. On smelting, these ores gave a speiss, metallic in appearance but brittle and of no practical use. The miners of that time, unable to refine this material, saw therein the workings of 'Kobold,' the German word for goblin; hence the name of one of the metals included in this speiss.

The manufacture of cobalt blue continued in Saxony until 1880, when cobalt-bearing deposits were discovered in New Caledonia. In the meantime, Brandt had separated the metal whose impure oxide had been used for so many years to colour glass. Bergman, in 1790, proved cobalt to be a chemical element.

Metallic cobalt was used for the first time in 1910 as an alloying addition for high-speed steels. Since then, cobalt has become an indispensable constituent in many alloys possessing, according to the type, remarkable high-temperature strength, special magnetic properties, good resistance to wear, etc.

Heat-resisting alloys

The special features of these, known as 'superalloys,' are their high mechanical strength at elevated temperatures and their good resistance to corrosion by hot gases.

Their use has increased rapidly as a result of the development of gas turbines and jet engines. The temperatures and stresses to which certain parts of these engines are subjected call for the use of special materials adapted for these applications.

The first heat-resisting alloys used were the age-hardenable chromium-nickel austenitic steels.

The partial replacement of iron and nickel in these materials by cobalt has resulted in the Fe-Cr-Ni-Co alloys, some of which are still used on a large scale in the manufacture of turbines.

Nickel-base alloys are always sufficiently rich in chromium to have good corrosion resistance. Additions such as aluminium and titanium impart precipitation hardening characteristics to these alloys. Many materials in this category have been improved by replacing part of the nickel by cobalt, and thus the distinction between nickel-base and cobalt-base alloys becomes rather difficult to establish. There are, however, some cobalt-base superalloys containing no nickel. As these are usually difficult to forge, they are used in precision-cast parts.

Since 1952, many studies have been carried out to improve the nickel-base alloys, some of which have developed really remarkable properties.

At present, cobalt supplies being amply guaranteed, investigators may profitably undertake research work on cobalt-base alloys, many of which can be further improved. The development of cobalt-rich age-hardenable superalloys should be possible. Boron additions to known alloys have already shown promise.

Increasing the cobalt content in certain nickel-base alloys has resulted in such improvements in their properties that other similar investigations should be undertaken.

Finally, vacuum melting has recently led to the development of wrought alloys with excellent high-temperature properties.

The present superalloys withstand temperatures of the order of 900°C.; future improvements are expected to raise their operating temperature to an ultimate value of over 1,000°C. At higher temperatures, other materials would have to be used, such as cermets or molybdenum, which withstand

temperatures of 1,500°C. The brittleness of cermets, however, presents problems which must still be resolved. As to molybdenum, its low resistance to oxidation requires the developing of protective coatings.

Difficulties in the manufacture of these new materials will limit their use to cases where very high temperatures are absolutely necessary, and the superalloys will thus retain their position in many applications.

Permanent-magnet alloys

The characteristics of magnetic materials for the manufacture of permanent magnets are:

(*a*) Residual induction (B_r expressed in gauss) which is the induction retained by the magnet at zero field.

(*b*) Coercive force (H_c expressed in oersteds) which is the reverse field necessary to completely demagnetize the magnet.

(*c*) Maximum value of the product ($B \times H$) which is the maximum magnetic energy per unit volume of the material.

The first cobalt steel for permanent magnets was developed in 1916 by Honda, a Japanese scientist. It contained 0·9% carbon, 5% tungsten, 6% chromium and 35% cobalt. Its $(BH)_{max}$ reached 950,000 gauss-oersteds and was three times greater than that of the chromium or tungsten steels previously used.

The Fe-Ni-Al alloys were discovered in 1930. At first they contained 12% aluminium and 25% nickel and had a $(BH)_{max}$ of 1,400,000 gauss-oersteds. A cobalt addition improved considerably the properties of these alloys, and the aluminium-nickel alloys have now been completely replaced by the aluminium-cobalt-nickel alloys known as Alnico. These contain 12 to 25% nickel, 5 to 25% cobalt, 5 to 11% aluminium, occasionally some titanium and copper, and iron to bring the analysis to 100%.

The Alnico alloys cannot be forged or machined. They must be cast to final dimensions. The shape of the cast pieces must allow as uniform a cooling as possible, since variations in the cooling rate of the magnet produce magnetic heterogeneities, which are but partially remedied by subsequent heat treatment.

This treatment generally consists of a high temperature solution treatment followed by oil quenching and ageing. In this way, a $(BH)_{max}$ of 1,700,000 gauss-oersteds may be reached.

The Alnicos may be made anisotropic by cooling in a magnetic field after the solution treatment. The magnetic properties are thus improved in the direction of the applied field at the expense of those in other directions. This improvement is particularly important for cobalt-rich Alnicos. Ticonal G, for example, which contains 8% aluminium, 24% cobalt, 3% copper, 14% nickel, and approximately 50% iron, has a $(BH)_{max}$ of 5,000,000 gauss-oersteds after treatment in a magnetic field.

By carefully controlling cooling from the molten state, it is possible to favour the growth of columnar crystals. By further applying a magnetic field parallel to the direction of growth of the columnar crystals, it has proved possible to obtain a $(BH)_{max}$ of 11,000,000 gauss-oersteds in Ticonal XX, which contains 34% cobalt, 15% nickel, 7% aluminium, 4% copper, 5% titanium and approximately 35% iron.

The Alnico-type alloys can also be manufactured by sintering. This process gives magnets with slightly lower but more homogeneous properties, the magnetic heterogeneities due to differences in cooling rates in cast magnets being non-existent in this case. Furthermore, the sintered Alnicos possess higher mechanical properties and can be shaped with greater precision than cast alloys.

The ferrites, or 'ceramic magnets,' are a new class of magnetic materials. They consist of a mixture of iron oxide and oxides of other metals such as barium. The powders are mixed, compressed in a die of proper shape, sintered at about 1,000°C., and cooled to 300°C. Cooling from this temperature to room temperature is done in a magnetic field oriented according to the desired direction of preferential magnetization.

In general, ferrites have a higher coercive force than the Alnicos; on the other hand, their residual induction and energy product are lower.

The following conclusions may be drawn.

(1) For the same magnetic energy, Alnico magnets are smaller.

(2) For efficient use, ferrite magnets should be shorter and have a larger cross-section than the Alnicos. The replacement of the latter by ceramic magnets will require, therefore, a modification in the form of the equipment in which they are to be used.

(3) The high coercive force of ferrites gives them remarkable resistance to demagnetization by a reverse field. The ferrite magnets may therefore be used in magnetic circuits comprising large air gaps. They can be handled with fewer precautions than metallic magnets, whose properties are adversely affected by the proximity of another magnet, by temporary interruption of the magnetic circuit, or by the distortion of polar fluxes.

Yet another class of magnetic materials is being developed. Basing his research on the theory of single domains, Néel has shown that it is possible to obtain permanent magnets by sintering very fine powders of ferromagnetic materials. Theoretically, a $(BH)_{max}$ of 50,000,000 gauss-oersteds should be obtained with a mixture containing 70% iron

and 30% cobalt, provided that elongated particles are produced, all of which should be oriented parallel to the direction in which the magnetic field is applied during compression. So far, magnets with a $(BH)_{max}$ of 5,000,000 gauss-oersteds have been obtained by this method.

In spite of competition from ferrites, the amount of cobalt used in the manufacture of magnetic alloys shows no tendency to decrease.

Tool and wear-resisting alloys

Since a number of alloys containing cobalt are used both in the manufacture of tools and in producing abrasion-resistant parts, these two applications have been grouped under the same heading.

The manufacture of tool steels was one of the first applications for metallic cobalt. In 1913, Schlesinger pointed out that an addition of 5% cobalt increased the life of high-speed steels. It was not, however, until after World War I that this improvement was applied in industry.

Cobalt raises the melting point of high-speed steels, increases the carbide solubility in austenite and diminishes the tendency to grain growth. It retards tempering after quenching and inhibits the precipitation and coalescence of carbides. It therefore increases the resistance to tempering and improves hot hardness. Its presence is particularly useful when the cutting edge of the tool is subjected to high temperatures.

High-speed steels may contain up to 20% cobalt, approximately 0·8% carbon and various amounts of tungsten, molybdenum, chromium and vanadium. They are used for tools which must withstand the heat caused by the high speed of cutting, and the abrasion of the material being cut.

Steels of nearly the same composition, but having a lower alloying element content and lower carbon content, are used in punches and dies for hot work.

The Stellite-type alloys containing 40 to 65% cobalt, 25 to 35% chromium, tungsten, molybdenum and above 1% carbon, are also used for the manufacture of tools, usually in the form of inserts. They also serve for parts subjected to wear and are particularly suitable when good resistance to abrasion and corrosion at high temperature are simultaneously desired. The Stellites are frequently used as hard-facings applied by arc or gas welding.

Many different components may be hard-faced with Stellites, *e.g.* dies and punches, shear blades, tools, milling cutters, bearings subjected to high temperatures and difficult to lubricate, diesel engine valves, parts of pumps and grinding mills, transporter screws, excavator teeth, etc.

The amount of cobalt used each year in hard-facing materials has a tendency to increase, while it decreases, however, in the manufacture of high-speed steels because of the competition from cemented carbide tools. The latter materials are composed of a hard constituent, *e.g.* tungsten carbide, and a binder, such as cobalt. The two constituent powders are mixed and compacted into inserts. These are preheated to a temperature between 700 and 1,000°C. to give them sufficient strength for machining to final dimensions. They are then sintered at 1,400°C.

Cobalt is the binder that gives best results with tungsten carbide. It dissolves part of the carbide during sintering to form a liquid phase of relatively low melting point which coats the undissolved parts of the carbide grains. On cooling, the carbides which have been dissolved precipitate and the cobalt forms a thin film around the grains.

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Miscellaneous alloys

Ninety-five per cent. of the metallic cobalt consumption is used in the manufacture of the alloys discussed above. Some interesting applications which, up to the present time, require only small amounts of cobalt metal account for the remaining 5%.

Low-expansion alloys. Superinvar (Fe 63·5%-Ni 31·5%-Co 5%) and Stainless Invar (Fe 36·5%-Cr 9·5%-Co 54%) have a very low coefficient of thermal expansion, which may be considered as nought in the case of the second alloy. These materials are used where the constancy of the dimensions must be strictly respected, such as geodesic instruments, length standards, high precision variable condensers, etc.

Constant modulus alloys. Alloys such as Co-Elinvar (Co 57 to 60%-Fe 25 to 35%-Cr 8 to 15%) and Velinvar (Co 56 to 63%-Fe 29 to 34%-V 7 to 10%) have a modulus of elasticity which varies very little with temperature. They are used in the manufacture of hair-springs for precision instruments and chronometers.

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corrosion resistance in air. It is particularly suitable for the manufacture of springs for watches and other precision instruments.

Haynes Alloy No. 25 (Co 52%-Cr 20%-Ni 10%-Fe 2%- W 15%- C 0·15%) has proved very suitable for springs used at high temperatures.

Finally, copper-base alloys containing from 1 to 3% beryllium and 1 to 2% cobalt are used in springs that must have good electrical conductivity.

Electrical resistance alloys. The Kanthal alloys containing 38% chromium, 3·5% aluminium and 2·5% cobalt are used in the manufacture of electrical resistances which must withstand temperatures above 1,350°C. They are not affected by sulphur-containing atmospheres. Konel, Cobanic and Hilanic, which contain cobalt, nickel, iron and titanium, are used in the manufacture of radio tube filaments because of their high electrical resistivity and good heat resistance.

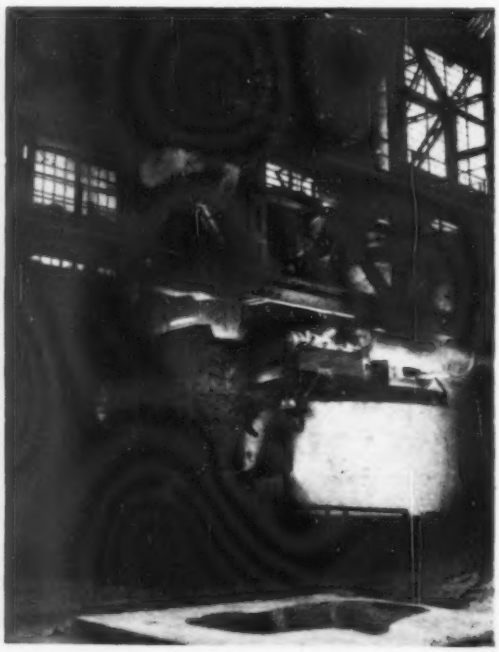
Radioactive cobalt. On exposing cobalt to radiation from a nuclear reactor, a radioactive isotope of atomic weight 60 is obtained. It has a half-life of five years and is used in industrial radiography and in radiotherapy.

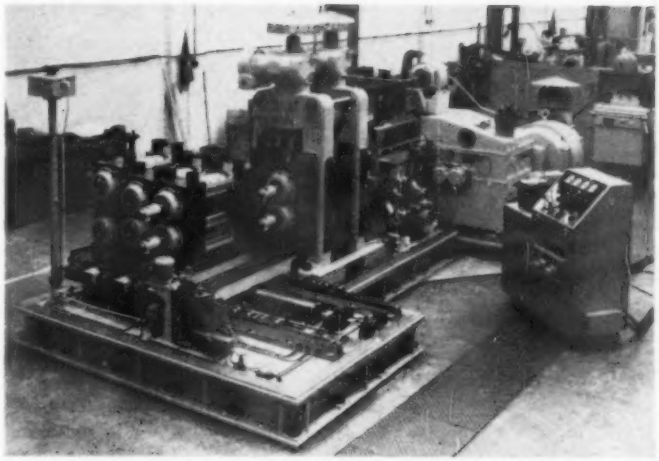
THE KRUPP INDUSTRIAL EMPIRE

BY THE RECENT ACQUISITION of a majority holding in the shares of Gussstahlwerk Bochumer Verein, the interests now controlled by Herr Krupp von Bohlen und Halbach are practically back to their pre-war size. And in spite of a statement of Allied Government policy in 1951 that in no circumstances would Herr Krupp be allowed to resume ownership or control of these interests, it does not appear likely, or indeed feasible, that he will be deprived of his present position.

The two pictures below show operations in progress in the Krupp plant at Essen. On the left an operator is removing a surface defect from a forging ingot with an oxy-acetylene torch, the ingot being held in a manipulator prior to forging. On the right is a view of the hot-blast cupola of an improved type, from which high-grade pearlitic and nodular cast irons can be turned out in batches of up to 50 tons.

Photographs by Teddy Schwarz





Rolling nuclear fuel elements

THE GROWTH in the last few years in the application of atomic power has focused interest on the problems involved in processing metal in the fabrication of fuel elements for nuclear reactors. The utilization of the heat of the fission process for power generation and other industrial purposes is influenced by the design of the reactor core and its fuel element components. Depending upon the design of the reactor, fuel elements can take a variety of shapes and configurations including (*a*) flat, curved and corrugated plates; (*b*) solid and hollow slugs; (*c*) rods; (*d*) tubes; (*e*) plate, slug, rod and tube assemblies, etc., and in addition to containing uranium, thorium, and plutonium in metallic or compound form may involve non-fissionable materials including stainless steel, aluminium, magnesium, zirconium, beryllium, titanium, nickel, chromium, copper, silicon, niobium, and molybdenum and their alloys. The production of plate and sandwich form elements might derive from the mill shown.

Although plutonium 239 is not amongst the most radioactive materials, it has been found necessary to handle it with extreme care and very rigid safety regulations are laid down against the relatively low penetration ability and to prevent the inhalation of plutonium-bearing dust. One safety precaution adopted is to enclose the equipment by means of a 'glove box' which can be of stainless steel and perspex or glass and is usually fitted with neoprene gloves entering the enclosure for operation of the plant within. A further advantage of this type of enclosure is that an inert gas at a small negative pressure can be introduced enabling the rolling to take place of materials which would otherwise suffer from oxidation.

Since at this initial stage the quantities involved in individual fuel-element fabrication orders are likely to be small, most establishments and companies likely to enter this field desire to limit their capital investment as much as possible, consequently while conventional practice could call for a 2-high hot breakdown mill, a 2-high cold intermediate mill, a 4-high cold sheet finishing mill and possibly a form rolling mill, an obvious preference arises to use a single machine capable of handling the entire rolling needs. Hence has arisen the development of the Stanat/Mann 2-high/4-high combination mill, arranged for rolling of difficult metals employing all the roll configurations mentioned earlier.

Albert Mann's Engineering Co., having already supplied specially designed small mills of this nature to A.W.R.E.; Commissariat a l'Energie Atomique, in France; Centre D'Etude Pour Les Applications de L'Energie Nucléaire in Belgium; Culcheth Laboratories of the U.K.A.E.A. and the Dounreay Establishment of the U.K.A.E.A., were reapproached by Commissariat a l'Energie Atomique to consider a similar application but involving a much heavier mill.

Combination mill

The 10-in. dia. by 14-in. face width 2-high/4-high combination mill is the culmination of ideas formulated in designing the smaller mills referred to above, but carried a stage further to enable the changing of the roll assemblies to take place by powered means because of the larger weights involved. The remote control of this mechanical changing of the roll assemblies brings with it, however, many problems which do not appear with manually operated mills.

The basic design incorporates the use of four

separate roll configurations which are automatically and remotely interchanged. The mill has a 600,000 lb. maximum rolling-load capacity at a speed of 100 ft./min., is fitted with an infinitely variable speed 2 h.p. screwdown motor drive and a 100 h.p. electronically controlled Ward-Leonard-type main mill drive. Screwdown pressure gauging and metering of the torque transmitted through the universal joint spindles have been incorporated. It is arranged for sealing within a glove box enclosure, the reduction gears and pinion stand and the drive motor being outside.

The roll changing mechanism is actuated from the control desk and requires the selection by a switch, of whichever roll assembly the rolling operation to be performed necessitates. Operation of the change button brings about the following complicated electro-hydraulic sequence: (1) disconnection of the screwdown from the top roll, (2) elevation of the screwdown to a position which will accept any roll configuration, (3) withdrawal of the jibs which retain the chocks in position in the mill housings, (4) withdrawal of the roll assembly on to the roll carriage, (5) support of the universal spindles whilst withdrawing the roll assembly, (6) indexing of the roll carriage to line up the new roll assembly selected, (7) adjustment of the universal spindles to cater for the roll centres of the selected roll assembly, (8) entry into the mill of the new roll assembly, (9) locking into position of the chocks by the jibs, (10) collection of the new top roll assembly by the screwdown mechanism with, it should be noted, prevention of any major screwdown pressure being applied when there is no material between the rolls.

Control equipment

The control equipment, developed by Albert Mann's Engineering Co., is very flexible in operation over the required speed range, shows economy in capital cost over conventional methods of control and is based on a new technique of pulse-controlled thyratrons, for which patent application has been made. The pulse-control method is used because it is independent of anode wave form, does not drive the grid positive at any time and in consequence stiff control of the firing angle may be obtained without the use of feed-back control.

Due to the compactness of the electronic components, a space saving for the equipment itself and for spares storage can be obtained of something in the order of 8 to 1. The control console, which can be seen in the illustration, not only incorporates the variable-speed control for the 100 h.p. mill drive but also incorporates the 2 h.p. variable-speed screwdown motor control, all the relays, etc., associated with solenoid control of the hydraulic circuits, and also incorporates the amplification and recording required by the torque and screwdown pressure system. Very high orders of speed stability and control can be obtained with this equipment enabling close automatic control of tension and the comparatively simple introduction of programme control.

Anodized aluminium windings

COMMERCIAL PRODUCTION of continuously anodized aluminium foil and strip for electrical windings, particularly in magnets and transformers, is under way at Tyne Chemical Co. Ltd., River Drive, South Shields. Anodized material from 0·002-in.-thick aluminium foil up to 0·06-in. strip in widths of a maximum of 12 in. continuously anodized in lengths of 1,000 yd. is being produced. The breakdown voltage figures reached under this new technique are the highest yet obtained in this field.

Flat windings of foil or strip with equivalent conductivity of a copper wire winding can be equal in volume, and in some cases smaller, notwithstanding the fact that the conductivity of aluminium in the 99% to 99·5% purity range is approximately 59% to 61% that of copper. Aluminium is also much lighter and in this form provides an improved heat-transfer rate across the coil eliminating the hot spots encountered in circular cross-section windings. Adjacent layers have only turn-to-turn voltage difference, eliminating the need for thick layer insulation commonly associated with round wire windings.

Anodized foil or strip can safely withstand considerable periods of overload, allowing designs to be of normal rating without providing for large safety factors.

The building up of an oxide film to enable aluminium foil or strip to be used as a conductor 'sheathed' with its own insulation is the basis of the method.

Consistent thickness, density, hardness and absence of pores, together with flexibility of the film, are all features which must be given careful consideration. Corrosive resistance of the anodic film varies with the alloys on which it is being produced. It is greatest on commercially pure aluminium and least on alloys containing large amounts of copper or zinc.

The breakdown voltage depends on the alloys, film thickness, texture and moisture content, but is not affected by increases in temperature up to 400°C.

The vulnerability of insulating materials based on organic compounds at high temperatures has been a strong influence on design within the electrical industry. Anodized foil or strip may be allowed to heat far beyond temperatures permissible in conventional windings.

Carbide impregnation

1 LEFT *The complete Wickman Impregnator.* 2 ABOVE *An electrode in use*

A NEW UNIT, known as the Wickman Impregnator, has been developed by Wickman Ltd. to enable a hard layer of sintered carbide material to be applied to metallic workpieces, enabling greater wear resistance to be obtained.

Experience has been gained so far primarily in the field of metal working and wood working, but additional experience in other fields of application is constantly being obtained. The following are typical examples of applications where increased tool life may reasonably be expected by the application of a carbide layer to the 'wearprone' areas of the tool: (*a*) Drills, taps, and single-point turning tools; (*b*) press tools, including the localized treatment of stressed sections in large dies; (*c*) extrusion dies; and (*d*) forging dies.

The carbide layer

The carbide layer on the workpiece is obtained from the electrode by a localized sparking action. Because of this, every portion of the treated area will not receive the maximum depth allowed for by the setting of the equipment. It is not recommended, therefore, that the treated surface should be ground or lapped.

The carbide is not merely deposited on the work surface but penetrates the parent metal and builds up on to it. The penetration of the surface, which may be seen in the transition zone shown in fig. 3, effectively prevents peeling-off of the carbide layer in service. The thickness of the layer is in the order of 0·003 in. on the 'coarse' setting and 0·0005 in. on the 'fine' setting of the machine.

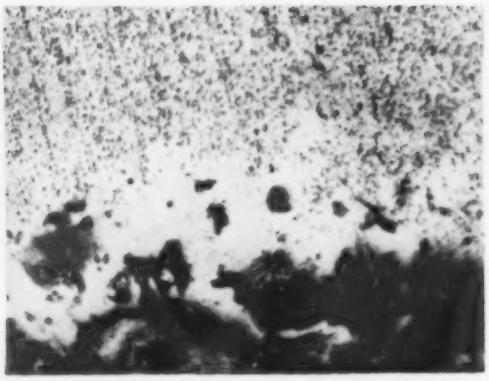
The applied layer of carbide will differ somewhat in physical characteristics from the original electrode material, this being due to a hyper-quenching action. Enlarged micrographs of the deposited surface indicate that the surface is covered by surface cracks. In effect, therefore, the carbide is in a series of islands which render it resistant to shock loads.

The somewhat unusual metallurgical pattern of the surface should not be taken as being detrimental, as the results achieved in practice show that the life increase of treated tools may well be two to four times, and cases of ten times have been recorded in certain applications.

The treated surface

Because the carbide is applied to the work surface by means of a spark discharge, the surface is characterized by a number of saucer-like depressions, the roughness of the surface being greater on the 'coarse' setting of the machine.

In appearance the treated surface is relatively rough and dull, and the degree of roughness varies considerably so that no useful purpose is served by taking surface measurements. The results achieved indicate that substantial advantages can be obtained



3 *Transition zone showing penetration of carbide into parent metal of workpiece*

without endeavouring to improve the treated surface by grinding or lapping.

A high-speed steel extrusion die for aluminium was treated and, despite the apparent roughness of the treated surface, the finish obtained on the extruded section was found to be quite acceptable. Furthermore, the treated die produced more than 120 billets without having to be removed for cleaning of the 'pick up,' whereas the die in its untreated state had to be cleaned after each five billets.

When considering the area of application, it is important to bear in mind that the whole object of imparting a carbide layer to the work is to increase the resistance to wear. It follows in consequence that the area of the workpiece to be treated is that which suffers the maximum degree of wear when used in the untreated state.

It may be that, on a single-point lathe tool, failure is caused by cratering behind the cutting edge under the action of the chip flow. In this case it would not be necessary to treat the top land of the tool up to the cutting edge, but only over that area where the chip is in contact with the tool.

Description of equipment

A two-position selector switch provides a means of controlling the depth of the carbide layer. The 'coarse' position will give a more rapid rate of coverage, but a coarser surface. The 'fine' setting will give a better surface, but the covering time will be somewhat greater.

The electrodes consist of rods of carbide material of a grade specially developed for the process.

The cost of treating 1 sq. in. of flat surface works out at about 2*s.* to 2*s.* 6*d.*, including carbide, labour and overheads, and the time required on the 'fine' setting which would be used for cutting tool applications is about 5 min.

Titanium pressing lubricants

'Gredag' molybdenum disulphide grease (Grade MP 30), made by Acheson Colloids Ltd., has been adopted as a titanium pressing lubricant by the De Havilland Aircraft Co. Ltd. following tests carried out by its Production Research Department. Comparative tests of the Acheson product and two other lubricants proved that it was more economical and efficient in operation. Referring to the cost of the lubricants, De Havilland's state in their report that Grade MP 30 costs one-third that of a comparable product tested. The results were the more impressive because they were obtained from the pressing of titanium, one of the most difficult metals to work.

Comparative tests of lubricants

The lubricants used on the drop hammers when producing hot titanium pressings were costly and were causing trouble on the dies due to molybdenum disulphide build-up. Lubricants are necessary to prevent scoring of the pressings.

All lubricants were tested on the same production run of pressings. Approximate blank area of each pressing was 1½ sq. ft. The greases (Product 1 and 'Gredag' grease grade MP 30) were both applied with a brush; (2) was sprayed. A record was made of lubricant quantities used.

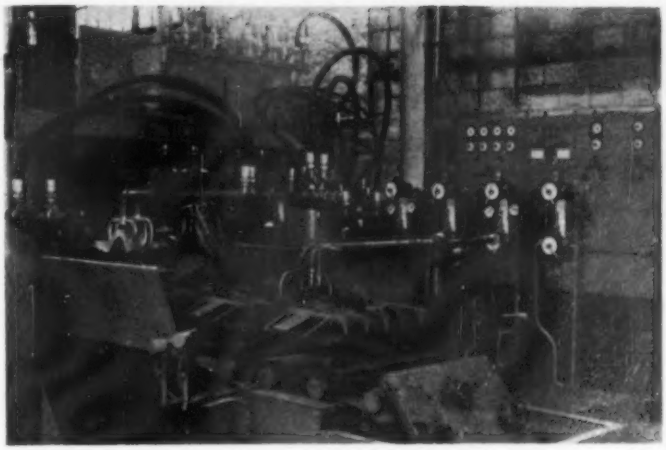
Results Product 1 gave good pressing results but was viscous and hence difficult to apply. The fumes caused by the hot pressing in contact with the grease were unpleasant. The molybdenum disulphide tended to build up into hard lumps in certain areas which were difficult to remove.

Product 2 gave score-free pressings. There was considerable loss of lubricant from overspray during application and molybdenum disulphide build-up was experienced.

'Gredag' grease grade MP 30 gave good pressings, did not build up and was more pleasant to work with due to its being easier to apply than Product 1. It gave off slightly unpleasant fumes.

Application The time taken to apply a grease or to spray Product 2 was for practical purposes the same. Although Product 2 was expected to save time this was not the case, due to the fact that the operators have to be very careful to get the right quantity in the right place, *i.e.* on sharp radii.

Cleaning tools Using Product 1 or 2 it was usually necessary to clean the tools twice for each 100 average pressings to remove the build-up molybdenum disulphide. This cleaning usually takes five minutes, therefore for each 100 average pressing ten minutes is wasted. No cleaning is necessary using 'Gredag' MP 30.



Flame-hardening

Use of Oxy-town's gas

1 *Peddinghaus automatic oxy-town's gas flame-hardening machine for hardening excavator track link components*

MANY WORKING PARTS of excavators are subjected to considerable wear by abrasion—dust and mud accounting for much of this trouble. It is essential that these components have hard, tough wearing-surfaces. It is only the working surface, however, which requires hardening; the core has to be left in its normal condition. The flame-hardening method enables a deep, hard case to be obtained quickly and economically, and it has been found the most satisfactory process available.

One of the components which has to work under the worst possible conditions is the track link. The wearing parts on this are the four holes which bear on the track pin, two heavy lugs which take up the drive from the sprocket, and the roller path which runs on the trailer wheels.

To design a machine which would automatically harden each link uniformly was a problem, in view of the awkward shape and considerable weight of the component. The firm of Paul Ferd. Peddinghaus of Gevelsberg, Western Germany, undertook this task and this machine, as well as the other plant described, has been installed by Surfard Ltd. at the Lincoln Works of Ruston-Bucyrus Ltd.

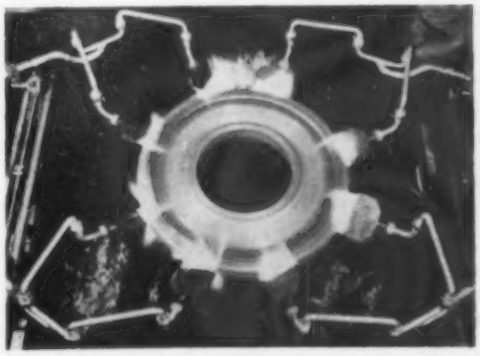
Link-hardening machine

Claimed to be the largest of its kind in the world, the link-hardening plant, Type BKG, comprises a heavy conveyor having eight stations and four burners. Lug hardening is accomplished by means of the spot method. As the track link is moved to the current position the conveyor stops and the specially shaped water-cooled burners are shifted horizontally to the heating position, where they descend over the lugs and ignite from a pilot flame. On reaching the required temperature they are displaced by spray quenches.

The roller path is hardened by the progressive method, the quenches being situated just behind the burners. The link remains stationary, while the burner and quench assembly moves over the length to be hardened at the correct speed to ensure the correct depth.

At each station a photo-electric device ensures that the burners cannot be ignited unless the component is in position. Operations are controlled by a pre-set programme selector. Gas and oxygen supplies for each set of burners are fitted with flow meters and pressure gauges, so that a method sheet

2 *A gear being heated by the oxy-town's gas burners just before reaching the hardening temperature*



can be made out for each type of link to be treated. Town's gas, enriched with oxygen in the proportion of 60 cu. ft. of oxygen to every 100 cu. ft. of gas, is used for the process.

Flame-hardening of large gears

Just installed at Lincoln is the first machine in this country to flame-harden large gears by the spinning method. The maximum capacity of this model is a 40-in. gear dia., and a tooth width of 4 in.

The machine comprises a tank in which the quenching oil is contained, at the centre of which a rotatable spindle is situated, and on this the gear is supported horizontally by means of a suitable adaptor. A number of oxy-town's gas burners are arranged around the circumference of the gear. Two milliscope automatic temperature controls are arranged, one set tangentially to measure the temperature of the tip of the tooth, while the other is set radially to pick up the temperature at the root of the tooth.

The gear is rotated between the burners by means of the spindle and, when the tips of the teeth reach the hardening temperature, the oxygen is automatically reduced by a pulsating relay from the first milliscope so as to prevent overheating, thus allowing the remaining part of the tooth to reach the pre-set hardening temperature. When this figure is obtained, the burners are automatically extinguished and the gear lowered into the quenching oil. A flow of compressed air is so directed across the surface of the quenching medium as to eliminate the possibility of igniting the oil. A built-in cooling device, coupled with an electric thermometer, maintains the oil at the required temperature.

Heating time for hardening a spur gear 39 in. in diameter, having 124 teeth of 4 d.p. and a width of 4 in., is approximately 20 min. if hardening down to the root is required.

Flame-hardening truck frames

The automatic oxy-town's gas flame-hardening machine Type LSW has been specially designed to harden the internal gear and roller path of truck frames on which the cabin and the excavating equipment rotate. The teeth of the gear are hardened by the progressive method, the burners to which the water spray quenches are attached rising over the length of the tooth.

The roller path is automatically hardened by the progressive method, the burners and quenches remain stationary, while the component rotates.

Quick-heat furnace

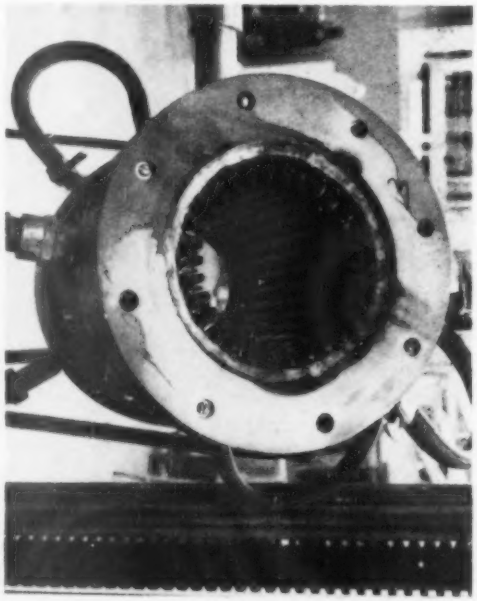
TO ENABLE MATERIALS TESTING at elevated temperatures, Boeing Airplane Co., Seattle, Wash., U.S.A., have developed what is claimed to be a unique quick-heat furnace which will reach 3,500°F. (1,927°C.) in 90 sec.

This high temperature is supplied by quartz heat lamps, 30 of which are arranged in a circle with a copper water-jacket cooling system around them, the standard lamps being operated at over twice the manufacturer's rating. The maximum power has been increased from 1,000 to 2,700 watts per lamp and the cooling system effectively prevents the lamps and connectors from melting. The inner surface of the furnace is gold plated for better heat reflection.

Power for the furnace comes through a pair of Ignitron electronic power regulators, the use of which permits immediate control of the heating and the time required to reach the operating temperature. Although most material testing is programmed for a constant temperature, the Ignitrons permit heat cycling if desired.

Material testing is carried out in conjunction with a universal testing machine and the material under test is then placed so that it runs vertically through the centre of the furnace, permitting tensile testing under simulated high-speed flight conditions.

Besides material testing, however, this new quick-heat source has a variety of uses, one of which is to test insulators at high temperatures in the aerial research laboratory at the Boeing works.



NEWS

Manufacture of permanent magnets

PERMANENT MAGNET making previously carried on by English Steel Rolling Mills Corporation Ltd. is transferred to English Steel Magnet Corporation Ltd., North Street Works, Openshaw, Manchester, which is a newly formed wholly owned subsidiary of the parent company, English Steel Corporation Ltd., Sheffield.

Plant for the production of permanent magnets, including well-equipped machining, heat treating and testing departments, has now been concentrated under one roof, and the completion of this scheme provides a good opportunity for introducing unified control and administration. It is with this object in view that a new company has been formed. Chairman of the Magnet Corporation is Mr. R. G. H. Taylor, and Mr. E. J. C. Patrick, formerly manager of the tool steel department, has been appointed director and general manager. Mr. F. S. Beale and Mr. P. Turrell have also been appointed directors, and the new Corporation's secretary is Mr. A. M. Simmers.

The Electroflo service training school

The Electroflo Meters Co. Ltd. opened its training school in October, 1958. Since then 18 mechanics have attended two-week courses. Representatives have been accommodated from Fisons Ltd., Winthrop Laboratories Ltd., A. E. Reed Ltd. and the Central Electricity Generating Board. Typical industrial instruments for the measurement and control of process variables are discussed, demonstrated, assembled and calibrated, with particular emphasis upon maintenance.

Such was the success during the first three months of the school's existence that the 1959 enrolments are on an increasing scale. Six courses have been planned during the first six months of the year.

Annealing plant for malleable castings

A major contract of approximate value £120,000 has been awarded to Birlec Ltd. by Ley's Malleable Castings Co. Ltd., for additional electric furnace equipment for the annealing of pearlitic malleable iron castings from their new mechanized foundry at Derby.

With an average output of 1 ton/h. the plant will comprise three main parts—a high-temperature furnace, a fast cooling conveyor, and a low-temperature furnace. Both furnaces will be of the type employing pusher mechanisms to progress trays of castings from end to end. Fully automatic means will be employed for transferring castings from the high-temperature trays to the cooling conveyor and thence to the low-temperature trays. Thus no manual handling operations will be required between the charge and discharge ends of the line. The trays will be of open type, and scaling of the castings during treatment will be avoided by the appropriate use of a controlled atmosphere.

Pearlitic malleable, which has a combination of properties suited to many engineering uses, particularly in the automobile industry, is in increasing demand. To ensure the production of castings with the highest properties, a special annealing cycle must be employed: at the conclusion of the first stage of the anneal, the castings must be rapidly cooled, a condition that can only be fulfilled with continuous equipment of the kind specified.

Mond Nickel Fellowships

The Mond Nickel Fellowships Committee now invites applications for the award of Mond Nickel Fellowships for 1959. The main object of these fellowships is to enable selected applicants of British nationality and educated to university degree or equivalent standard to obtain additional training and wider experience in industrial establishments, at home or abroad, so that, if they are subsequently employed in executive or administrative positions in the British metallurgical industries, they will be better qualified to appreciate the technological significance of research and to apply its results.

There are no age limits, though awards will seldom be made to persons over 35 years of age. Each fellowship will occupy one full working year. It is hoped to award five fellowships each year of an approximate value of £900 to £1,200 each.

Full particulars and forms of application can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed application forms will be required to reach the Secretary of the committee not later than June 1, 1959.

General view of new heat-treatment shop for the production of permanent magnets at the English Steel Magnet Corporation Ltd.

The new interlocking aluminium ingot — Alcan — is of convenient shape for furnace charging

New shape aluminium ingot

Aluminium Union Ltd., the distributors here of 'Alcan' aluminium, have introduced a radically new type of 'interlocking' 50-lb. ingot which is safer, easier and faster to handle during transport and by the users. This follows an extensive programme of development and testing in the field to secure the best ingot shape which would take full advantage of mechanical handling equipment.

The company is in the process of converting completely to the new ingot as its standard for the 50-lb. form of 99·5% aluminium, but meanwhile only limited quantities of the new ingot are available.

The new design ensures that in strapped bundles the ingots are locked together in the three dimensions, vertical, lateral and lengthwise. Two metal straps serve to secure a neat bundle of 40 ingots, making a convenient 2,000-lb. unit which stands up well to shocks in transit and can be stacked six-high with other bundles to form a stable pile. The straps, which are prevented from slipping by the wasp-waist design of the ingots, can readily be removed. The bundle is then free-standing and stable and individual ingots can easily be lifted out for handling and furnace charging. Unstrapped bundles or part-bundles can be moved by fork-lift truck. The stability of the bundles will contribute to safety and enable better use to be made of shipping and storage space and of mechanical handling equipment.

International Congress on Electro-Heat

Nineteen papers by British authors are to be presented at the fourth International Congress on Electro-Heat to be held at Stresa, Italy, from May 25 to 29. Altogether 199 papers will be given to the ten sections into which the congress will be divided. The number of delegates notified at the end of 1958 was 580, of whom 39 are British.

Among the papers dealing with electro-heat and the metallurgical industries are the following:

'Development of electric smelting in the British Commonwealth,' Dr. A. G. Robiette, D.SC., F.I.M., Birlec Ltd.

'Electric surfacing heating for industry,' Mr. H. Reik, M.SC.(ENG.), M.I.E.E., M.I.MECH.E., Isopad Ltd.

'Electro-heat in the fabrication of aluminium,' Mr. A. J. Jones, B.SC.(ENG.), A.M.I.E.E., Northern Aluminium Co. Ltd.

'The control of large electric-arc furnaces in relation to their effect on the supply system,' Mr. J. W. S. Payne, B.SC., A.C.G.I., British Thomson-Houston Co. Ltd.

'Vacuum induction-melting and casting,' Mr. F. L. Gladwin, Wild-Barfield Electric Furnaces Ltd.

'Induction-melting furnaces,' Mr. A. G. Allen, Birlec Ltd.

'Interstage annealing with M.F. induction heating,' Mr. K. A. Zandstra, A.M.I.E.E., Philips Electrical Ltd.

'Developments in resistance-heated vacuum furnaces,' Mr. M. Donovan, General Electric Co. Ltd.

'Electricity supplies to large electric-arc furnaces; Some technical and economic considerations,' Mr. A. Haddock, B.SC., M.I.E.E., Yorkshire Electricity Board.

'A mains-frequency induction holding furnace for gravity and low-pressure die casting,' Messrs. M. Gibbs and R. H. Barfield, Wild-Barfield Electric Furnaces Ltd., and Mr. E. C. Lewis, Alumasc Ltd.

The British National Committee on Electro-Heat was reorganized about a year ago and its members now are: British Electrical and Allied Manufacturers' Association, British Electrical Development Association, British Iron and Steel Research Association, British Non-Ferrous Metals Research Association, Department of Scientific and Industrial Research, Electrical Research Association, Electricity Supply Industry (through the Electricity Council, Electricity Boards and the South of Scotland Electricity Board), Institute of Metals, Institution of Electrical Engineers, Iron and Steel Institute.

Remote control by V.H.F.

Gilmoor Control Systems Ltd., Abbey Road, Park Royal, N.W.10, a company owned by Electroflo Meters Co. Ltd., is engaged in the manufacture of a remote control and indication system employing a v.h.f. radio link. The system is employed for remote control and the position indication of 16 water pumps raising and transferring water from an oasis to an installation of the Qatar Petroleum Co. in the Persian Gulf. The control station and the controlled pumps are seven miles apart.

At the present moment, private radio transmission between fixed points is not permitted by the G.P.O., but there is every likelihood that this will change soon and then it will be possible to have remote radio control of gas, water and electrical installations. It is expected that the finished equipment should be available for demonstration in a few weeks' time.

Industrial film festival

At Harrogate, on April 21, the second Festival of Films in the Service of Industry will be opened by the Rt. Hon. Viscount Chandos, with the president, Lord Godber, presiding.

Speaking in London last month, Lord Godber said that 'the detailed planning of the festival is now very well advanced, and the response has been extremely satisfactory. When the list closed towards the end of January, 260 films in nine categories had been entered competitively for the festival.' Lord Godber said that 'the viewing panels will finish their work this week, and it is expected that just over 100 films will be selected for showing at Harrogate.'

PEOPLE

THE INSTITUTE OF METALS has made the following awards of medals:

The Institute of Metals (Platinum) Medal to **Dr. Leonard Bessemer Pfeil,** O.B.E., A.R.S.M., F.I.M., F.R.S., director, the Mond Nickel Co. Ltd., in recognition of his outstanding contributions to non-ferrous metallurgical science and to the non-ferrous metals industries.

The Rosenhain Medal to **Prof. Robert William Kerr Honeycombe,** M.SC., PH.D., Professor of Physical Metallurgy, University of Sheffield, in recognition of his outstanding contributions in the field of physical metallurgy.

The W. H. A. Robertson Medal and Premium to **Dr. Raymond Bernard Sims,** M.I.MECH.E., A.INST.P., chief engineer, Davy & United Engineering Co. Ltd., for a paper on 'Automatic-gauge-control in rolling mills,' published in the *J. Inst. Metals*, 1957-58, **86.**

Mr. E. W. Voice, who has been associated with BISRA since 1946, has recently been appointed assistant director of the British Iron and Steel Research Association.

He joined the association in that year to work under Dr. H. L. Saunders, the head of the Ironmaking Division, at the Normanby laboratories. For a short period in the winter of 1951-52 Mr. Voice was seconded to the United Steel Companies Ltd. to lead a team at Appleby-Frodingham concerned with the provision of design data for 'Seraphim' sinter plant. In May, 1952, he joined the National Coal Board's Central Research Establishment as assistant director to Dr. J. Bronowski, and was eventually appointed acting director to the newly-formed Mining Research Establishment of the board at Isleworth (Middx.). He returned to BISRA in June, 1954, when he succeeded Dr. Saunders as head of the Ironmaking Division. He combined this with the position of head of BISRA's chemistry department in September, 1956.

Mr. Voice was formerly in the research laboratories of the Gas Light & Coke Co. In 1938 he received an honours degree in physics at the University of London. From 1939 to 1946 he was seconded to the Ministry of Supply, working on chemical warfare projects.

The West Midlands Branch of the Institute of Export has appointed a new chairman, **Mr. P. W. Underhill,** who is chief shipping officer at Birlec Ltd.

Mr. Underhill joined the Branch in 1939 and was elected to the local committee in 1950. Two years later he was elected chairman of the Branch's Programme and Social Sub-Committee and later became vice-chairman of the Branch. Mr. Underhill was appointed a member of the National Council of the Institute in 1953.

He has been with Birlec Ltd. for 27 years and became chief shipping officer in 1950.

Mr. James H. Barwell, a director of Allcock & Co. (Metals) Ltd., Birmingham, is the newly elected president of the British Bronze and Brass Ingot Manufacturers' Association.

Northern Aluminium Co. Ltd. announces that **Mr. E. L. Ashley,** manager of Banbury Works, is to undertake a special assignment for the company and will be leaving for North America shortly after Easter. He will be succeeded by **Mr. C. I. F. Mackay,** who is at present assistant works manager and production manager at the Rogerstone Works.

Mr. C. I. F. Mackay

It was at Banbury Works that Mr. Mackay joined the company in 1931; he became production manager in 1939 and moved to Rogerstone in 1951 to take up a similar appointment there. He is a native of Banbury and well known in the district.

Mr. Ashley has been manager at Banbury for over a quarter of a century and was, in fact, a member of the survey team that selected Banbury as the site for the plant in 1929. He joined the organization in 1927, working in Britain and Canada before coming to Banbury as sheet mill manager in 1931. He succeeded Mr. R. D. Palmer as works manager in 1933 and has directed the expansion of the plant in the ensuing years. During the war he was also manager of the Adderbury 'shadow factory.'

From 1933 to 1936 Mr. Ashley was a town councillor and, well known as an enthusiastic yachtsman, he was some years ago elected life president of the Banbury Sailing Club.

OBITUARY

PIONEER IN THE application of science to industry, **Mr. Frank** Twyman, F.R.S., died last month. His original work in spectrochemical analysis, particularly in continuing and developing the work of Bunsen and Kirschoff in the application of spectroscopy for the analysis of metals, is known among metallurgists everywhere. In particular his design of a fixed adjustment quartz spectrograph which allowed the ultra-violet region of the spectrum to be used was revolutionary in its conception.

Born in 1876, he had a sound technical education before joining Fowler Waring Cables Co. Ltd. Shortly afterwards, however, he went to Otto Hilger, who had succeeded his brother Adam Hilger in charge of the firm of that name. Otto Hilger died in 1902 and Mr. Twyman succeeded him as manager, becoming managing director in 1904 when the firm was incorporated. He was managing director until 1946, and two years later, when the firm amalgamated with E. R. Watts & Son to become Hilger & Watts Ltd., he continued as a director until 1952 and then became technical adviser until his death.

He was elected a Fellow of the Royal Society in 1924 and in 1926 was awarded the John Price Wetherell Medal of the Franklin Institute of Washington, in 1927 the Duddell Medal of the Physical Society, and in 1957 the Gold Medal of the Society of Applied Spectroscopists of the U.S.A.

NEW PLANT

High-vacuum pumps

A range of high-efficiency rotary piston pumps has been introduced by Genevac Ltd. for vacuum equipment used in many branches of scientific research—industrial, medical, educational and also in manufacturers' standard productions.

Fig. 1 shows the 'Genevac' single-stage high-vacuum rotary piston pump which is of 2, 4, 8 and 12 cu.ft./min. capacity with an ultimate vacuum of less than 0·005 mm. Hg. The double-stage model is of 2, 4 and 6 cu.ft./min. capacity with an ultimate vacuum of less than 0·0002 mm. Hg. The design permits of higher pumping speeds at 100 microns and the pressure rise is less than 0·5 mm. Hg with maximum ballast. The necessity for oil changes is reduced to a minimum due to the oil circulation filter system.

These pumps are now in production by Genevac Ltd., a new subsidiary of General Engineering Co. (Radcliffe) Ltd. New works at Radcliffe, Lancs., have been established to permit of specialization in the design and manufacture of a wide range of vacuum equipment.

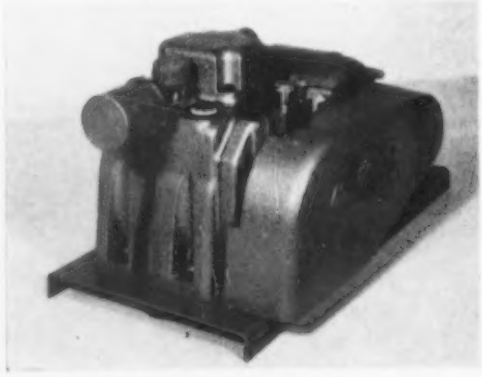
New smoke eliminator

An important contribution towards cleaner air, particularly in so far as the smokeless operation of industrial boiler plant is concerned, is being made by a newly-established engineering concern which is now manufacturing under licence smoke eliminators designed and developed by the Fuel Research Station of the Department of Scientific and Industrial Research. Apart from ensuring that smoke emitted conforms with statutory obligations under the Clean Air Act, the installation of these new eliminators is claimed to effect substantial savings.

Two types are currently available, one for natural-draught hand-fired boilers, and the other for similar boilers with forced draught. The company is also marketing a new smoke density indicator, also developed by the Fuel Research Station of D.S.I.R., which is said to provide a simple, efficient and immediate means of detecting the emission of dark smoke.

Further information is available from Lynward Engineering Co. Ltd., 180 Brompton Road, London, S.W.3.

1 *'Genevac' single-stage high-vacuum rotary pump*



2 *Gas cylinder trolley*

Gas cylinder trolley

The latest addition to the 'Powell' range of handling equipment is a new gas cylinder trolley. Constructed of tubular steel, it enables two gas cylinders of up to 12 in. dia. each to be carried in a well-balanced position without any need for securing chains. An ingenious hand-operated sprag permits easy loading and unloading. Fitted with two 16-in.-dia. main wheels and an 8-in.-dia. wheel in the rear swivel castor, the trolley is easily manœuvrable and is ideal for outdoor or indoor use. A welding rod holder is also supplied. The trolley can be obtained with rubber-tyred wheels, or all metal wheels. Single-cylinder trolleys are also available from the manufacturers, Powell & Co., Burry Port, Carms., South Wales.

Chromel-Alumel thermocouples

For many years it was thought impossible to maintain a bright finish on Chromel-Alumel wires during the long stabilizing heat treatments required to maintain consistent long-term accuracy. Because of this it has become customary for the tenacious oxide film to be scraped away before making connections or welding a thermocouple junction. This will no longer be necessary with Hoskins' Chrome-Alumel thermocouple alloys. It will lead to greater accuracy where millivoltmeter, rather than potentiometer, circuits are utilized, since the absence of an oxide film will give closer control over resistance values. The oxide film does, however, reform under normal service conditions, where it is needed to confer the outstanding resistance to corrosion typical of these alloys. R. G. McLeod Tools Ltd., Lavina Grove, London, N.1, are agents in the U.K. for these thermocouple alloys which have a useful temperature range up to 1,250° C.

Tube-packs for industrial greases

Several grades in the range of 'Gredag' industrial greases and compounds, marketed by Acheson Colloids Ltd., are now being packed in aluminium collapsible tubes manufactured by Venesta Ltd. Initially, the products available in tubes will be limited to certain grades containing molybdenum disulphide or graphite.

Acheson Colloids Ltd. adopted the new pack to provide convenient means of dispensing the more generally used greases, which were formerly available only in cans containing from 1 lb. upwards. Tubes are preferred by service engineers for certain applications because they are more economical, cleaner and easier to use.

Another high-temperature problem solved by

NIMONIC ALLOYS

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A SPECIAL TYPE of 'cruet' for suspending forgings vertically during heat-treatment has been developed by William Beardmore and Company Limited. Weighing 4½ tons, it consists of two main members of heat-resisting steel, joined together by bolts 4 ft. long. These bolts must carry the weight both of the lower member and a forging of up to 30 tons, through a continuous heat-treatment cycle involving temperatures of over 1,000°C for 12-hour periods.

Under these exacting conditions, the axle-type steel bolts which were first employed quickly failed through scaling and lack of mechanical strength. A mixed set was then incorporated, consisting of four bolts of heat-resisting steel and four of NIMONIC 75. After a period of service, it was found that the steel bolts had extended and become virtually useless, and that the bolts of NIMONIC 75 alone were supporting almost the entire load. Because of this proved superiority, 3-in. diameter bolts of NIMONIC 75 secured to NIMONIC 75 nuts are now employed in all the 'cruets' used by Messrs. Beardmore for handling large forgings, with smaller bolts of the same material for forgings of up to 8 tons.

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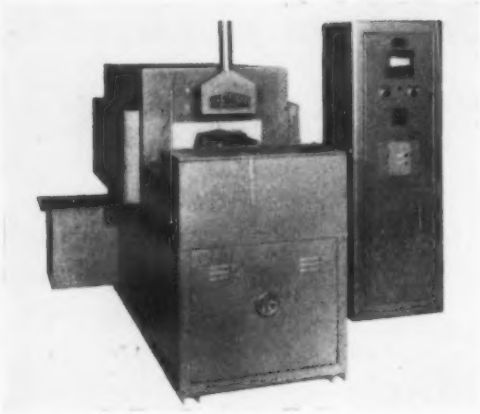


3 *18 kW. electric shaker-hearth furnace by Hedin Ltd.*

Electric shaker-hearth furnace

The shaker-hearth furnace, arranged to be used with artificial atmospheres, is useful for the bright hardening of carbon steels, and the bright annealing of ferrous and non-ferrous metals, such as pressings, stampings and machine parts.

Many improvements are included in the present design by Hedin Ltd. The shaker movement prevents flat components from jumping on top of one another, thus obviating inconsistency of heat treatment. The charge passing through the furnace can be regulated according to its weight and nature by an infinitely variable speed unit. Further, the arrangement of the elements can be adjusted to suit varying weights of charge, and care has been taken to prevent the cooling, even of the lightest charge, whilst it is on its way to the quench.

The hearth is of cast nickel chromium and can either be machined perfectly smooth or grooved to suit individual requirements. The hearth is housed in a gas-tight heat-resisting muffle, and is fitted with a water-cooled chute where it enters the oil quench, to prevent heat conducting to the oil.

Fig. 3 shows a standard model rated at 18 kW. and capable of 50 lb./h. The plant is supplied with a floor-mounted cubicle housing the electrical control gear. The quench tank can either be supplied fitted with work baskets, or mechanized to bring the charge out of the quench.

High-density sintered material

Johnson Matthey & Co. Ltd., Hatton Garden, London, E.C.1, are now producing and marketing Mallory 1000, a machinable high-density material composed of tungsten, nickel and copper and made by a special powder metallurgy technique. Mallory 1000 has a uniform structure, high strength and great density. As the material may be subjected to all normal machining and grinding processes, it is ideally suitable for the manufacture of components where high mass coupled with high strength and small volume are important considerations. Components fabricated from Mallory 1000 are finding increasing application as counterbalances for aircraft control surfaces, balances for flywheels, inertia members in such instruments as accelerometers, and as rotating inertia members, where strong precision-machined rotors are required in a limited space.

A further application of Mallory 1000 is in radiation shielding. By virtue of its physical structure and its very high density, Mallory 1000 effectively absorbs gamma rays and can also be used for the shielding of neutron-emitting fission by-products, provided that the intensity of bombardment is relatively low. Such low-intensity neutron bombardment causes only moderate activity in Mallory 1000.

Mallory 1000 is supplied in special pressed shapes as well as in the form of round and rectangular bars.

Investment base for precision casting

A new type of investment base for precision investment casting has been developed by Mellor Mineral Mills—one of the Dohm Group of Companies. It is being marketed under the trade name of investment base 350.

Originally confined to the jewellery industry, the new method is now being used by a number of foundries for the production of precision castings where machining cannot be carried out and where surface finish and tolerances are important. It was developed after extensive tests based on the original American cristobalite base.

According to the manufacturers, investment base 350 operates at a temperature of 1,450° C. It needs no additives, retarders or accelerators, only water to mix into a slurry. Setting time is 20 min.

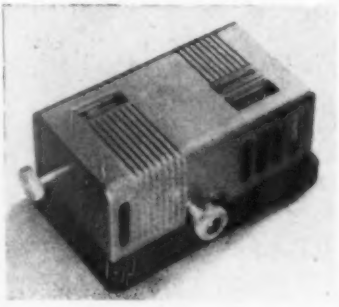
Thermostat for ventilator problem

A new thermostat is being used to solve a ventilating problem for factories and other large areas which use unit heaters and forced-air convectors for basic heating. An additional control takes over in hot weather to operate the fans when the heating plant is shut down.

A unit heater installation can now be controlled entirely from the thermostat, enabling the operator to run the equipment automatically as with a conventional thermostat, or continuously regardless of temperature factors. It also allows him to stop the fans completely when the space will be unoccupied for considerable periods.

The new features of the thermostat are based on a three-position manual control with a locking device which prevents it being altered by unauthorized persons or children. The three positions are: *automatic*, which brings the conventional function of the thermostat into operation; *on*, which allows the fans of unit heaters to turn even when the thermostat is not calling for heat; and the *off* position, which shuts the plant down completely.

Inquiries to: P. W. Kingsland, Honeywell Controls Ltd., Ruislip Road East, Greenford, Middlesex.



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Indian iron and steel symposium

To focus attention on the latest technological and research developments in the iron and steel industry and their rational utilizations, a symposium on the iron and steel industry in India was held by the National Metallurgical Laboratory, Jamshedpur, last February.

The symposium, which drew a large gathering of top-ranking scientists in different branches of iron and steel from all over the world, was inaugurated by Prof. M. S. Thacker, director-general, scientific and industrial research; Sir J. J. Ghandy, director-in-charge, Tata Industries Ltd., and chairman of the executive council of the National Metallurgical Laboratory, presided.

Dr. B. R. Nijhawan, director, National Metallurgical Laboratory, welcoming the foreign and Indian delegates, said that the various aspects of iron and steel technology starting from the raw materials to the finished products presented complex and intricate problems to be tackled by research organizations the world over. The National Metallurgical Laboratory had rightly recognized the urgency of tackling such research and development problems relating to iron and steel technology at an early stage. Systematic work had been done at the laboratory on raw materials of the iron and steel industry such as their beneficiation, sintering of iron ores, studies on their reducibility, and production of LD steel in the experimental converter, besides other problems of equal interest.

Low-shaft furnace pilot plant

The National Metallurgical Laboratory has also set up in collaboration with the Metals Committee of the Council of Scientific and Industrial Research a low-shaft furnace pilot plant, designed to produce 15 tons/day of pig-iron from high- or low-grade iron ores, utilizing non-metallurgical coals and lignite coke.

Sir Jehangir Ghandy, in his presidential address, pointed out that the symposium organized by the National Metallurgical Laboratory should give an impetus to the studies in hand and provide encouragement for further work both in the laboratory and on the shop floor. Sir Jehangir reviewed some of the latest developments in iron and steel technology and suggested their applications in India. He highly commended the research work conducted in this direction in the National Metallurgical Laboratory and extended, on behalf of the executive council, their deep appreciation to Dr. Nijhawan and his staff for the very valuable work being done by them in the laboratory.

Prof. M. S. Thacker, in his inaugural address, observed that the symposium was particularly significant in the context of India's second five-year plan. Despite the fact that India had substantial resources of iron ore, her *per capita* consumption of steel was very low compared to that of other industrially advanced countries of the world. It was, however, a happy augury, said Prof. Thacker, that the new steel plants in the public sector had started production, and this symposium rightly synchronized with the opening of Rourkela and Bhilai steel projects. The deliberations of the symposium in which many foreign and Indian experts were taking part would, no doubt, be a great contribution to the promotion of the industry in this country. Prof. Thacker paid tribute to Dr. Nijhawan and his research workers for the excellent work they were doing in the National Metallurgical Laboratory.

During the symposium, the Hon. Sardar Swaran Singh, Union Minister for Steel, Mines and Fuel, observed that in a country like India where there was a great shortage of metallurgical coal and considerable deposits of lignite and other non-metallurgical coals, methods had to be developed for using these non-metallurgical fuels for the production of pig iron. With this object in view, the low-shaft furnace pilot-plant project had been commissioned to investigate the possibilities of producing commercial grades of pig iron from low- or high-grade ore and non-coking coals. The results of the investigation to be conducted in this plant, he said, would be watched with great interest all over the country and abroad. The Minister paid a tribute to the valuable work of the National Metallurgical Laboratory relating to iron and steel technology and other research and development projects.

A total of 37 papers covering various aspects of iron and steel technology were presented and discussed. These papers are being published in the new *NML Technical Journal*, the first issue of which has just appeared.

Prof. M. S. Thacker inaugurating the Symposium on Iron and Steel in India last February

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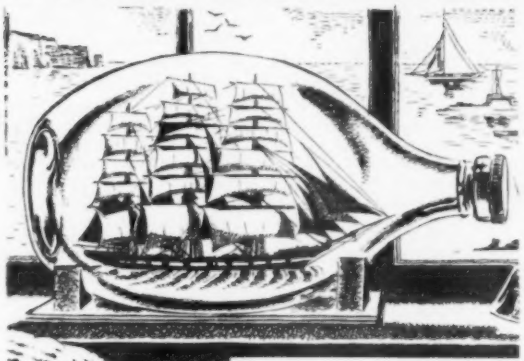

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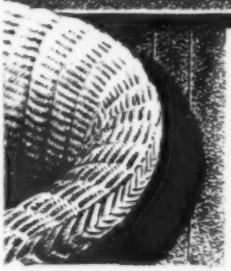

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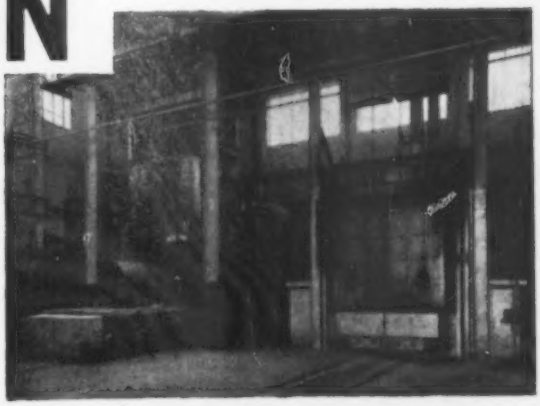

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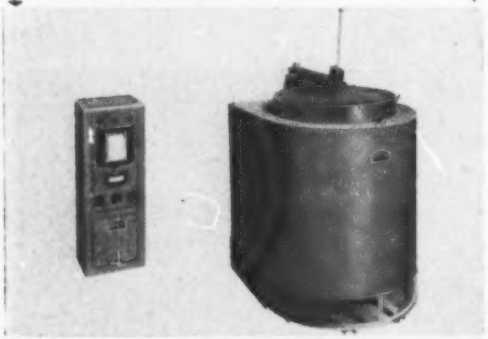

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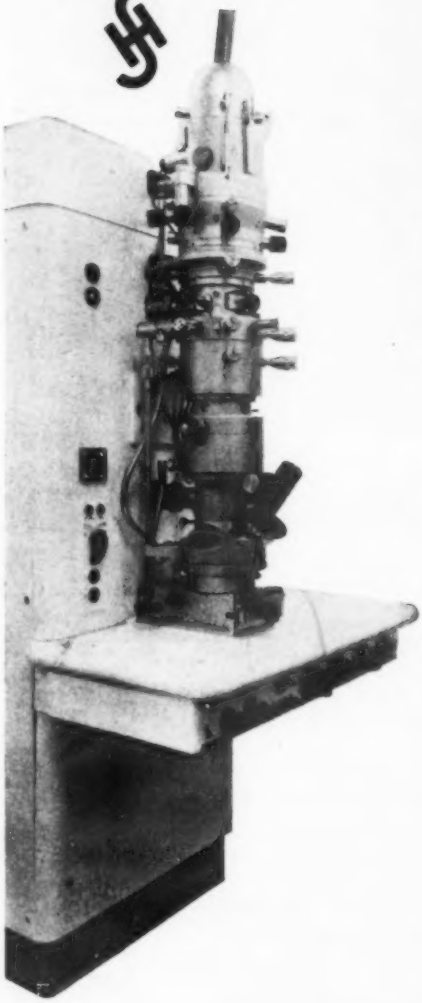

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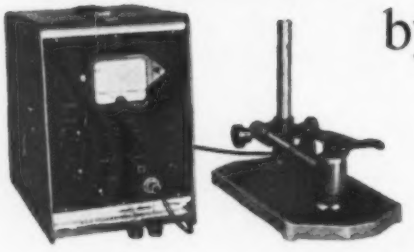

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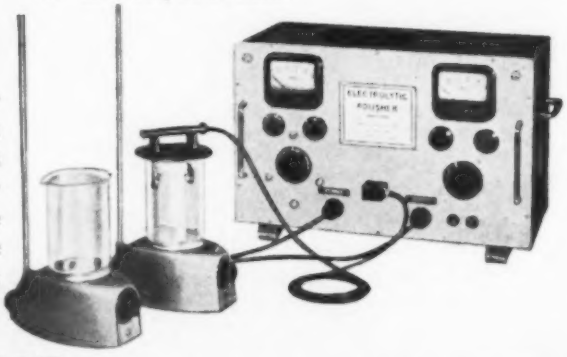

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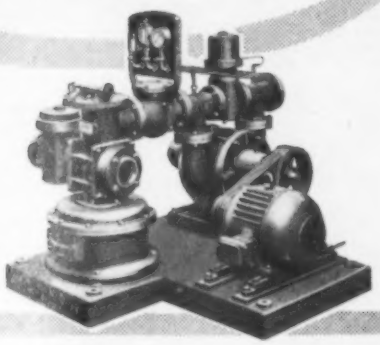

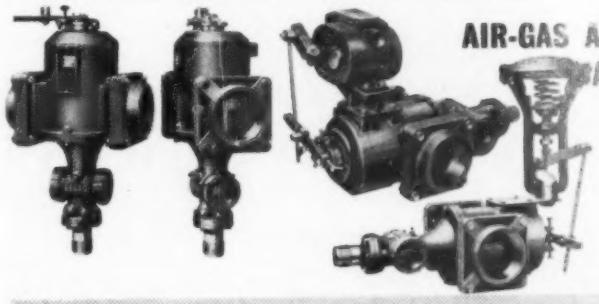

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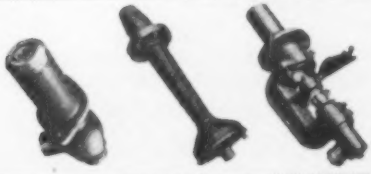

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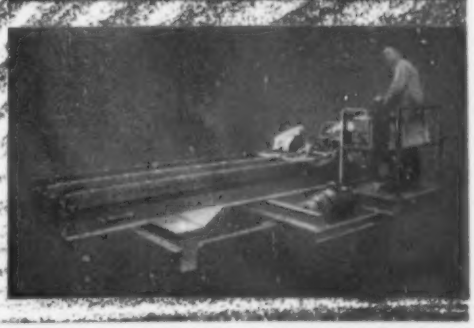

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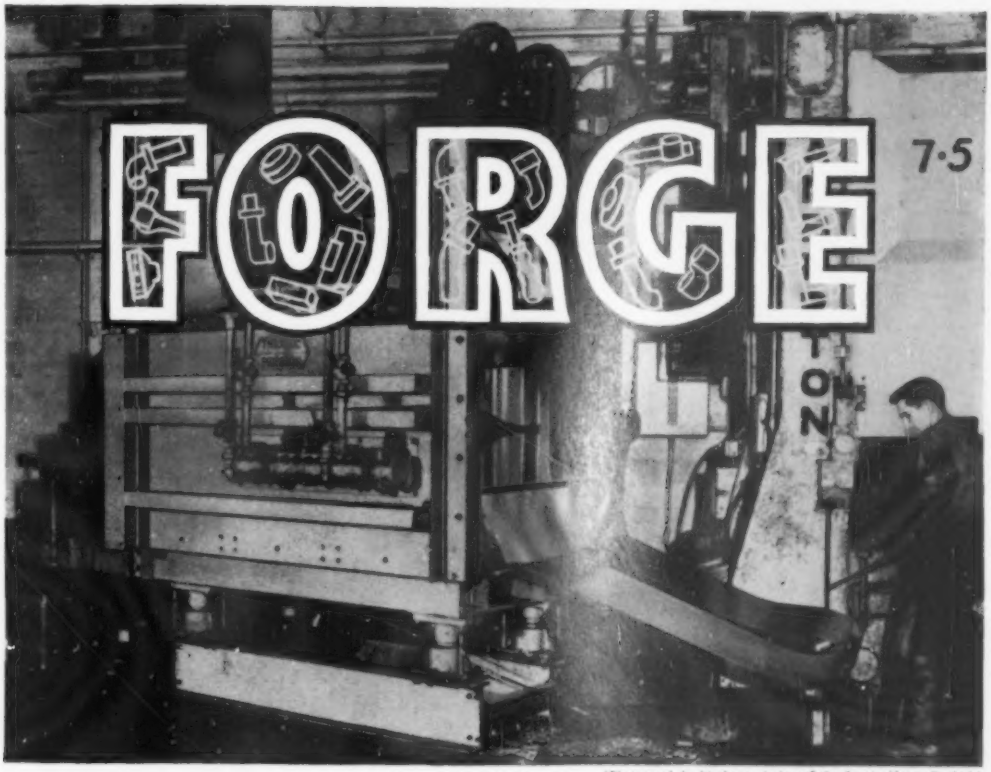

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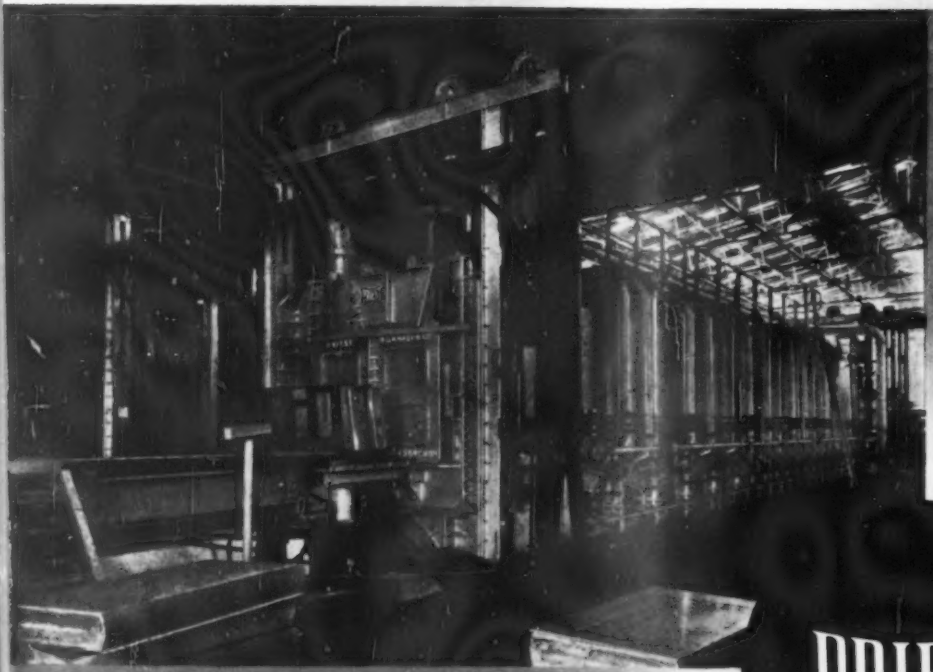

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